HOW TO FLY

BY A. FREDERICK COLLINS

The Book of Wireless

The Book of Stars

The Book of Magic

The Book of Electricity

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A. FREDERICK COLLINS

AUTHOR OF "KEEPING UP WITH YOUR MOTOR CAR," "THE HOME HANDY BOOK,"
"THE BOOK OF ELECTRICITY," "THE BOOK OF MAGIC,"
"THE BOOK OF STARS," "THE BOOK OF
WIRELESS," ETC.

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TO MY BROTHER

DR. T. BYARD COLLINS

WHO HAD FAITH WHILE OTHERS LAUGHED

A WORD TO YOU

Flyers are in great demand.

The United States Government wants men for its flying corps and you can be one of them.

To be an airman in time of war is not only less dangerous than fighting in the trenches but it is far more exciting, and, besides, it puts you in the front rank to win honor and glory.

Though it is not hard to learn to fly, there are but few who can handle an aëroplane at the present time; hence to be a pilot *now* means in a literal sense that you are a *superman*, for you are above your earth-bound fellows, at least when you are winging your way through cosmic space.

Now you may or may not know it, but the aëroplane is the speed machine of today.

It has been highly developed to meet the exacting and rigorous conditions imposed by the present war, and when the great conflict is over manufacturers will direct their energies toward supplying the need for sporting and commercial machines.

Aëroplanes, as they are now designed, constructed, and flown, are as safe, or safer, than automobiles, nor does it take much more mental and physical energy to

learn to drive them, but what it does take to fly is the kind of stuff that men are made of.

To be a flyer at this stage of the game will put you in the front rank of the birdmen, for the art is new and history is long. Therefore I say unto you: Learn to fly now. Leave this mundane spheroid under you and make short cuts over the hills and rivers and whatever other obstacles have heretofore impeded your two-dimensional travel, and go in an air line.

This is the age of the swift, by the swift, and for the swift; and the aëroplane is the last word in progressive achievement. Your opportunity to learn to fly is at hand today, so do it *now* and be ready to go to the front in an *escadrille*.

A. Frederick Collins.

The Antlers,
Congers, Rockland County,
New York.

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HOW TO FLY

CHAPTER I

HOW THE AËROPLANE WAS INVENTED

Ever since the days of the biblical Adam man has yearned way down deep in his heart to fly, and, what is more to his credit, he risked his precious neck in his attempts to do it.

It is thrilling to read about the early exploits of these venturesome souls in the air, but as this is a one-idea book—that is to tell you *how to fly*—the history of the pioneers of aviation is left to other writers, and I will begin with the first *heavier-than-air* machine, other than rubber strand models, that actually flew.

The Langley Aërodrome.—The Langley *aërodrome* (from the Greek *aer,* which means air, and *dramein,* meaning to run, or *air-runner*) was a model *aëroplane,* or flying machine, designed, built, named and successfully flown by the late Samuel P. Langley, Secretary of the Smithsonian Institution at Washington, in 1896, long before the first *man-lifting* machine ever got off the ground.

His aërodrome measured 12 feet from tip to tip; was driven by a steam engine and boiler that generated 1½ horse-power and weighed 7 pounds; the total weight of the model was 30 pounds, and it flew repeatedly over distances of half a mile and at a speed

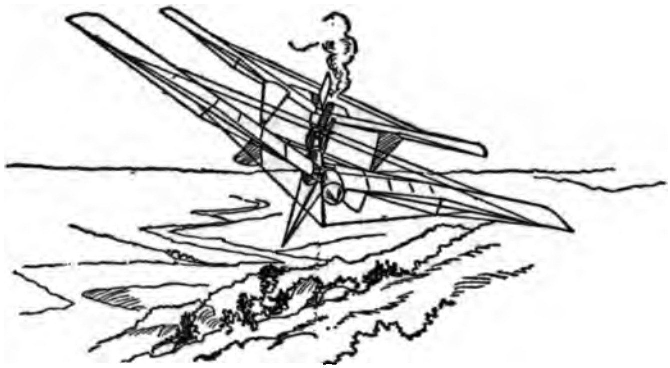

FIG. 1.—LANGLEY'S AËRODROME IN FLIGHT OVER THE POTOMAC RIVER, 1896

of from 20 to 30 miles per hour. It is shown in full flight in Fig. 1.

This beautiful little machine was the forerunner of the modern aëroplane, and the results obtained by Mr. Langley undoubtedly did more to stimulate the Wright Brothers to take up flying than anything else. A full account of the model is given in a booklet called "The Langley Aërodrome," published by the Smithsonian Institution. You can get a copy for the asking.

The Wrights' Aëroplane.—The Wright Brothers, Wilbur and Orville, of Dayton, Ohio, began to learn to

fly in 1900, using the sand-dunes of Kitty Hawk, North Carolina, for their proving grounds.

Their first experiments were made with a *glider*—which is nothing more than a kite with two *main-planes* or *wings,* and is nothing less than an aëroplane without the engine. To control the elevation flight of their

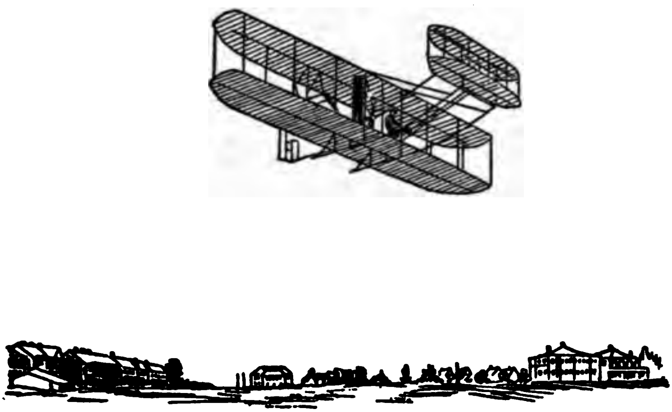

FIG. 2.—WRIGHT BROTHERS' AËROPLANE, FORT MEYER, VA., 1908

glider they fitted it in front with a pair of elevation planes, and to keep it balanced sidewise they invented the scheme of warping the wings, all of which is explained in full in Chapter IV.

To the end that they might learn the way of the machine in the air until it was second nature for them to control it, they practiced gliding for three years. The time finally came when confidence in their ability to fly led them to install a gasoline engine in the glider

and this was made to drive two propellers in the rear of the main-planes just as it does in the Wright machines of today.

With this new-born aëroplane they made, in December, 1903, the first motor-driven, man-carrying flight, which lasted for a small fraction of a minute. The first successful long-distance flight was made near Dayton, Ohio, in 1905. See Fig. 2.

It was not until September, 1908, though, that Orville Wright at Fort Myer, Virginia, and Wilbur Wright at LeMans, France, made their first record public flights, the former flying 1 hour, 14 minutes and 20 seconds, and the latter soaring in the air for more than 1½ hours with a passenger.

From this time on both records and necks were broken by other fliers who tried to outdo the inventors and to undo themselves. Common sense very largely prevails now and aëroplane accidents are seldom heard of.

CHAPTER II

HOW AN AËROPLANE FLIES

Haven't you often watched a bird winging its way across ravines and rivers and over woods and hills, and wished that you could speed through the air above them with the same swift and easy flight instead of having to walk slowly and with effort around them?

It is a wish that is born in everyone. But *how* a bird flies no one, not even the greatest scientist, could begin to tell until the very end of the nineteenth century.

And as for man ever being able to fly in a machine heavier than the air, why, everyone knew it was the one thing that could not be done. And this is the reason that, when you spoke of trying something which the folks back home thought to be impossible, made them say: "You can't do it any more than you can fly." And so, of course, you didn't try.

Yes, the problem of making a machine that would fly was so hard that only a few hare-brained fellows believed it could be done, while the wiseacres laughed and winked the other eye. And thus things moved on in the same old rut until the Wrights, then a couple

of bicycle mechanics, startled and thrilled the world by building and flying in an aëroplane or airplane as it is now called, and it was their turn, and the turn of those who had faith in mechanical flight to laugh.

The Way of a Bird.—You may or may not ever have thought of it, but birds use two different methods to fly; the first way is by flapping, or *beating,* their wings, and the second way is by getting a good start, then spreading their wings and *soaring.*

If you live in a country where there are eagles, or other kinds of large *soaring birds,* as they are called, and will watch one of them when it rises from the ground in flight, the first thing you will see it do is to spread its great wings a little, then start to walk and soon break into a run.

After running along aways it will begin to beat its wings, slowly at first and then, as it runs harder, it beats them faster and faster until it gets up speed enough to leave the ground. Once clear of the ground it keeps on beating its wings and flying forward and upward at a *small angle* until it has gathered enough *momentum* to carry itself through the air. Then it makes *planes* of its wings by stretching them out and its *speed* will carry it for miles without the slightest further effort on its part.

What Mechanical Flight Means.—Any machine that is heavier than the air, that carries its own power,

and that will fly, is a *flying machine,* and flying with such a machine is called *mechanical flight.*

Nearly all the early attempts to build a machine that would fly were made on the beating wing principle, but while models with beating wings have been made to fly, no machine of this kind was ever built that raised a man from the ground; and as the beating wing has nothing to do with the way an aëroplane flies we won't stop to consider this mode of flying.

Soaring flight, then, is the thing, and when it was found after a long while that a pair of outstretched wings, or planes, driven through the air *fast* enough would keep it sustained there as long as the power lasted, the aëroplane—the real flying machine—had its beginnings, and the how, why and wherefore of soaring flight will be told here.

There are two chief things you need to know to make the way an aëroplane stays up in the air by soaring flight clear in your mind's eye, and these are: (1) the action of the *air* on the machine; and (2) the effect of *speed* on the air. When you understand speed in its relation to the air you will have the whole theory of flight clear in your mind, and all the other things such as the *center of pressure, stability, propulsion,* etc., will come along easy and natural like.

How an Aëroplane Flies.—I will tell you in a few words just how an aëroplane flies, so that you will have

a clear idea of what the rest is all about as you come to it.

Make this experiment: take a board 6 or 8 inches wide and 3 or 4 feet long and strike the still surface of the water in a pond with the *flat* side of it and you will find that it acts as though it were a *solid body* instead of a *yielding fluid* at the moment the board hits it. Now it is the same way with the air; if you strike it *hard enough* with the flat side of a board, or a plane, it acts as though it is nearly solid, at the instant of impact, instead of just thin air.

A kite, or the wings of an aëroplane, is set at an angle so that when it is in flight the air strikes the under surface of the planes; this *deflects*—that is, turns the air down—and it is this force of the planes striking the air, or the air striking them, or both together, that keeps the machine from falling for a given moment, but it would fall the next moment if it were not for the *high speed* at which it is driven and which makes the planes keep on striking the air and so hold it up.

Now About the Air.—There is much more to the mixture of gases surrounding the earth, which we call the *air,* than we can see of it, and it allows many things to be done that could not be done if there were no such thing as air. Flying is one of them.

What the Air Is Made of.—The air, or *atmosphere,* as it is sometimes called, is simply a mixture of 1/5

part of oxygen, ¾ part of nitrogen and $\frac{1}{10}$ carbon dioxide with small traces of other gases making up the rest of it; and altogether it absorbs a lot of water vapor.

The Air Has Weight.—Though the air is made up of gases it has weight and so the air at the top presses down the air which rests on the surface of the earth; the *pressure* of the air at sea-level is, in round numbers, 15 pounds to the square inch, and of course the air is more *dense,* or compressed, at the bottom than it is at the top.

The Height of the Air.—As the eagle cannot fly higher than 3 or 4 miles, it is not likely that the aëroplane will beat this record by more than a mile or two. A balloon once ascended to a height of 7 miles, but the air was so thin that the aëronauts became unconscious.

It is believed that the definite limit of the air is reached at a height of about 50 miles and that at this height it has a surface like that of the ocean. On this surface great billows of air roll to enormous heights, and from the observation of *shooting stars* it is known that there are traces of air to a height of 200 miles or more.

The Air Is a Fluid.—The air is called a fluid because the particles of gases of which it is made change their positions one to the other just as they do in water or other liquids.

But, unlike water and other liquids, it can be *compressed* and, too, it is very *elastic,* which means that when it is put under pressure and the pressure is removed it *expands,* or spreads out, until it fills the same space that it did before the pressure was applied to it.

The reason the air expands is because the particles of gases of which it is made are always shooting out like millions of little cannon balls and they keep right on going until they hit other particles of gases, the surfaces of an aëroplane, or something else.

This constant *bombardment* of the particles of air is due to a lot of causes, but the continual change in temperature is the chief one, as it varies the density of the air; that is, heat makes the air expand when it gets lighter, while cold makes it contract and it gets heavier.

The Air at Rest and in Motion.—In flying we don't have to deal with *particles* of air as such, but with *masses* of air, that is, whole chunks of it at a time.

But as the particles of the air are heated by the sun and cooled more or less by the clouds and the night, the air in part, or as a whole, is never at perfect rest, for it moves from one place to another, sometimes gently as a zephyr and at others with the force of a tornado, in order to *equalize the pressure* of the air. We call this movement of the air the *wind.*

And so the air is always hurrying-scurrying along in fitful gusts and setting up here a rapid whirl and

there an air-pocket, and these have cost many an aviator his life because he couldn't see them.

What Inertia of the Air Is.—A ball, or anything else without life, cannot move or stop of its own accord and, what's more, when anything is *at rest* it takes *time* to start it going, and when it is *in motion* it takes *time* for it to stop. This sluggish action of things is called *inertia*.

To see how inertia acts, lay a newspaper on a table and put a plate on the paper. Now give the paper a double-quick jerk, pulling it clear from the table; the plate will stay exactly on the spot where you placed it. The reason the plate stays on the table is because you pulled the paper from under it so quickly the plate didn't have time to get into motion.

Although the air is so thin and light, still it has inertia, too, and as it takes *time* to start it moving this greatly helps to make it hold up an aëroplane, for before the air can be pushed from under the wings the aëroplane has passed over it and is sliding on other masses of air in precisely the same way that a skater glides swiftly across thin ice before it has time to break through.

What Air Pressure and Air Resistance Is.—If you ever flew a kite you know a good deal about what is called *air-resistance,* though you may never have thought much about it before.

You know, of course, that it is the *pressure* of the

air, that is, the wind, against the kite that keeps it from falling, and you know that it is the string that holds the kite against the wind and keeps it from being blown away. Fig. 3 shows how the wind blowing against a slanting kite holds it up as long as the string holds it in.

When the wind dies out and you have to "run like

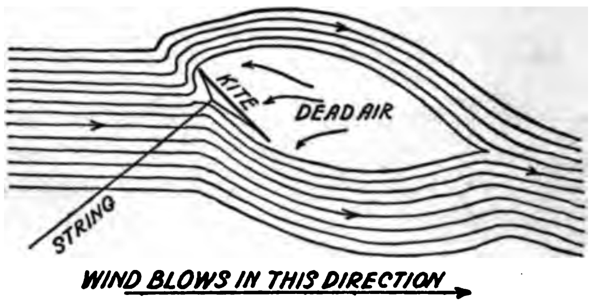

FIG. 3.—THE ACTION OF THE WIND ON A KITE

the divil when the road is livel" as did the Mulligan Guards of old, against the calm air, it acts a little differently from the way it does when the kite is still and the wind is blowing. But in either case the air and the kite *resist* each other and we only say that the one is still and the other moves because we size them up from the earth.

It must be clear now that while the resistance of the air opposes anything that moves *fast enough* through it, it is this very resistance that is caused by its *inertia* which acts not only as a support for a heavier than air

machine, but also permits the propeller to drive it forward.

Head and Skin Resistance.—So far we have talked

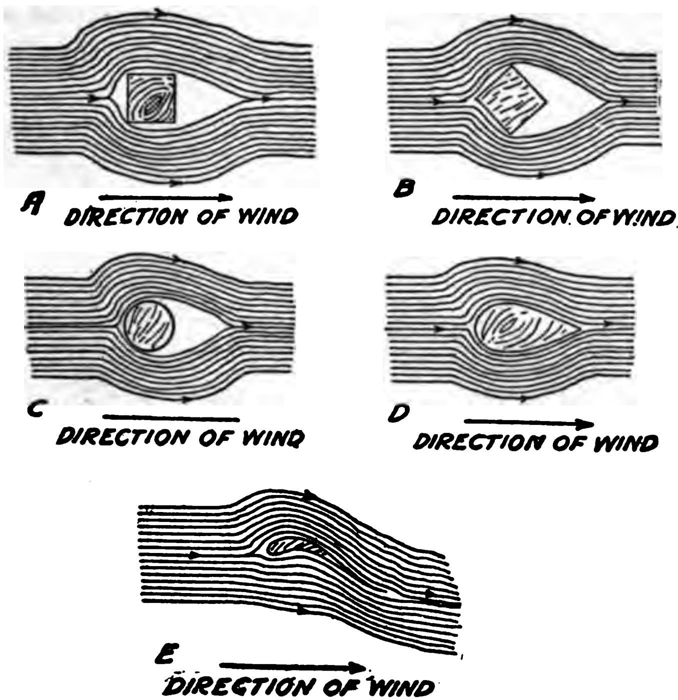

FIG. 4.—THE EFFECT OF DIFFERENT SHAPES ON HEAD RESISTANCE

about the air as a support for an aëroplane, and this is very good of it, but it also holds back the flight of an aëroplane by what is called its *head resistance,* and this is not so good.

Head resistance is caused by the air striking the different parts of the machine, and *skin resistance* is caused by the friction of the air as it slides over the surfaces of the machine. As it takes power to overcome the head resistance it must be reckoned with, but the loss of power due to skin resistance is a negligible quantity and, hence, need not be considered here.

As an illustration of head resistance let a wind of 40 or 50 miles an hour blow against a stick of wood a couple of inches square, as shown at A in Fig. 4; it will not only meet with a lot of head-on resistance, but it will form a partial *vacuum* behind it and it takes power to overcome this *drift,* as the *drag* of this *dead air* is called.

Now turn the sharp edge of the stick so that it will cut the wind, as at B, and, though it may seem a curious thing, the drift is but little less than when the flat side of the stick is held square against it, for the partial vacuum is formed back of it as before.

Again hold a round stick in the teeth of the wind and it will only offer about half as much resistance as the flat and the *dihedral*[1] surfaces of the square stick, but even then there is a drift of dead air, as shown at C.

But if you will whittle the stick into the shape of a fish, or *ichthyoid form,* as it is called, it will offer far

[1] Two plane surfaces, set at an angle like the wings of Langley's aërodrome shown in Fig. 1.

less head resistance than any of the other shapes, because the air streams around it and meets it at the rear end without producing a vacuum, as shown at D. For this reason not only the *fuselage,* as the body of the machine is called, but the *stanchions* which hold the mainplanes apart, and all the other parts should be given a fish-like shape, while the planes should be formed, as shown at E.

What Stability Means.—You will hear a good deal about *stability* when you come to work with *aëroplanes,* and as it is the thing that keeps your machine right side up—or for the lack of it lets it turn upside down—you ought to have a pretty clear idea of how it is had and, when it is once had, of how to keep it.

Stability is the factor which makes an aëroplane keep its balance when it is flying and which, should it start to upset either by a gust of wind striking it or by turning too sharply, tends to pull it up and cause it to right itself.

Make this simple experiment and you will quickly see the difference between a plane that is *stable* in the air and one that is *unstable.* Take a sheet of writing paper, say 8 inches on the side, that is, square. Hold it level, as shown at A in Fig. 5, and let it drop; you will see it dart first one way and then the other and often turn completely over before it reaches the floor. It is a very unstable piece of paper, as you will admit.

Now fold up the edges of the paper half an inch all round, as shown at B, and holding it level again drop it as before, when this time it will fall as straight

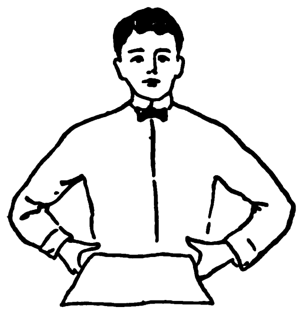

FIG. 5.—A. AN UNSTABLE SHEET OF PAPER

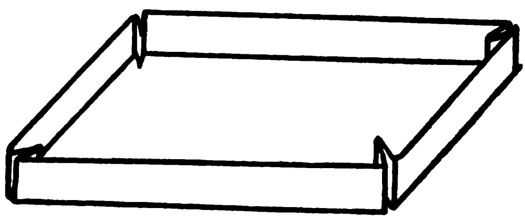

FIG. 5.—B. A STABLE SHEET OF PAPER

as a marble to the floor. This shows that you have added something that makes it wonderfully steady, and it also shows that fins on an aëroplane give it a good deal of stability.

An aëroplane must have two kinds of stability to keep it from taking a tumble, and these are: (1) *lateral stability*, which means that it is balanced *transversely*,

r crosswise; and (2) *longitudinal stability*, which is s balance *endlong*, or lengthwise. These conditions f balance, or *equilibrium* as it is called, depend (a) n the *center of gravity*, (b) on the *center of pressure*, nd (c) on a few other little things.

Lateral Stability.—It is easy to give a machine teral stability for changing air currents and sharp irns are all that ever disturb it. Long, narrow, and eeply curved planes help to secure lateral stability, nd fins, as I have mentioned, are a great aid.

Longitudinal Stability.—It is harder to give a ma-iine longitudinal stability, for the center of pressure, s you will presently read, is always shifting its posi-on and the pilot has to control it by changing the osition of his *elevating planes* or *ailerons*.

Then, too, if the *center of gravity* is too high or too w, or too far front or too far back, the machine will se its balance every time the center of pressure ianges. But by having the center of gravity at the ght point and the *thrust of the propeller* and the *mean* nter of pressure at the same point, the machine then is the longitudinal stability it needs to fly safely. nd now let's see just what the center of gravity and ie center of pressure mean.

What the Center of Gravity Means.—Of course ou know that *gravity* is the giant force that makes iings fall to the earth; that the pull of gravity is ways toward the center of the earth—that is, in the

direction of a plumb-line—and that its pull is measured by the *weight* of a thing.

The center of gravity of an object is at that point where it balances in whatever position it may be placed, and its whole weight acts as though it were bunched together at the point called the center of

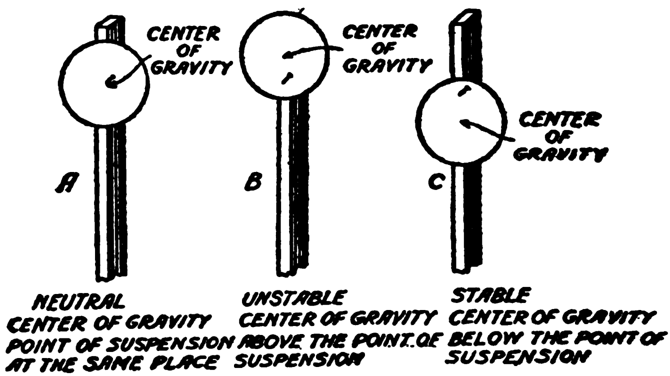

FIG. 6.—HOW GRAVITY ACTS

gravity, instead of being distributed all over it as it really is.

To demonstrate the center of gravity cut out a cardboard disk three inches in diameter, push a pin through its center and into a board, as shown at A in Fig. 6, so that it will turn freely. Now however the disk may be turned it will be perfectly balanced, and when this is the case we say it is in *neutral equilibrium*.

Take the disk from the board, push the pin through it, near the edge and into the board, as shown at

B; the center of gravity is high now and the slightest touch will topple the disk over, for it is in *unstable equilibrium.* Give the disk a start and it will turn to the position shown at C. You can swing the disk to and fro and it will always come back to the same point of rest, for the center of gravity is *low* and it is in *stable equilibrium.*

How to Find the Center of Gravity.—You can find the center of gravity of an aëroplane in this manner: First, find the weight of the front end by rolling the front wheels on a platform scale, and then find the weight of the tail by resting the skid on the scale. Be careful to have the machine horizontal when weighing both ends of it.

Now the *total weight* of the machine, W, is found by simply adding the weight of the front, or wing end, W1, to the weight of the rear, or tail end, W2, thus:

$$W = W1 + W2$$

Having obtained these weights, measure the distance between the axle and the skid. To find the longitudinal, that is, the lengthwise center of gravity, use the following formula:

$$D = \frac{d \times W2}{W}$$

where D equals the distance back of the axle that the longitudinal center of gravity will be, and is what you want to find, and d equals the distance between the axle and the skid, which you already know.

Thus, if the weight the wheels carry is 850 pounds and the weight the tail skid carries is 250 pounds and the distance between the axle and skid is 18 feet, then W = 850 × 250 or 1,200 lbs. and

$$D = \frac{18 \times 250}{1{,}200} \text{ or } 3.72 \text{ feet back of the front axle.}$$

If you will now draw a line through the longitudinal center of your machine 3.72 feet back of the front axle

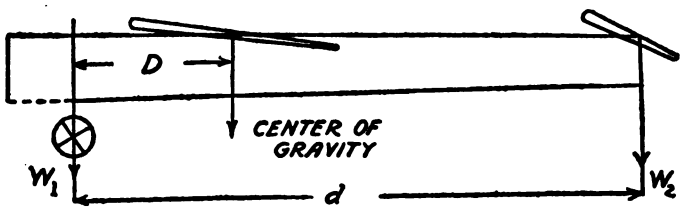

FIG. 7.—DIAGRAM SHOWING HOW THE CENTER OF GRAVITY IS FOUND

and perpendicular to the ground, as shown at D in Fig. 7, and draw a horizontal line through the center of the frame of the machine, the point where the lines cross will be very nearly the longitudinal and lateral centers of gravity, which is the true center of gravity of the machine.

What the Center of Pressure Means.—When air is blown against a surface of any kind or shape the *pressure* is distributed; that is, it is spread all over it, just as gravity pulls equally on all parts of a body; but there is a certain point on the surface the air is blowing on where the pressure *seems* to be *concentrated*, or

bunched, and this point is called the *center of pressure* —in just the same way as the weight of a thing seems to be bunched at a single point which is called the center of gravity.

But there is this difference: While the center of gravity is *always* fixed, the center of pressure changes

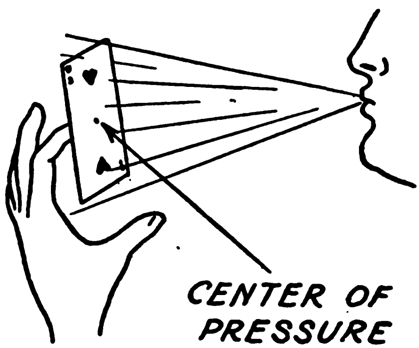

Fig. 8.—Experiment Showing the Center of Pressure

with every change of the angle the object makes on which the air pressure is acting. Look at Fig. 8 and make the experiment and you will see precisely where the center of pressure is and what it means.

Hold a playing card by its edges with one hand and put the tip of your index finger of your other hand about the center of the back. Now blow a stream of air on the front surface of the card and direct it so that the card will be pressed against your finger and stay there without being otherwise held, and this point is called the *center of pressure.*

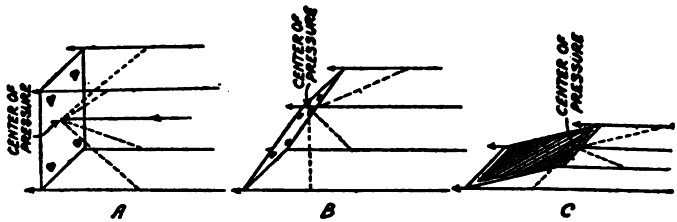

FIG. 9.—VARYING CENTERS OF PRESSURE

But the center of pressure need by no means be in the center of the card, for it changes as the position of the card is changed. To make this clearer let's suppose the center of pressure is in the center of the card,

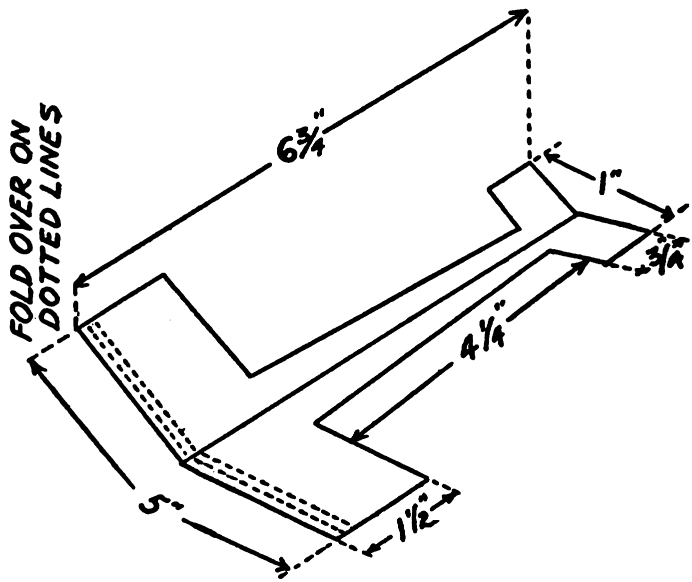

FIG. 10.—A SIMPLE PAPER GLIDER

as shown at A in Fig. 9, when it is held vertically. If now you tilt the card toward the horizontal, as shown at B and C, the center of pressure will shift from the center of the paper toward the front edge.

In precisely the same way the center of pressure of an aëroplane never stays at the same point, but shifts with the varying angles formed by the wing surfaces to the direction of the air opposing it.

The principle of this action can be easily shown by cutting a glider out of a sheet of writing paper, as in Fig. 10. Hold it level by the little end and let it drop to the floor and it will fall just as the sheet of paper did, that is, every which way.

Now fold the front edge of the large plane over two or three times to make it heavier in front and let it drop again; it will glide gracefully to the floor. The reason is that the center of gravity is brought forward to the *approximate* point of the center of pressure, and when they coincide they act together, instead of opposing each other, and the aëroplane is stable.

Finding the Resultant Center of Pressure.—The *resultant center of pressure* means the sum of the air pressures which act on the main plane at a given point.

The way in which the resultant center of pressure is found is to test a model of the main plane in a *wind tunnel.*

This gives what is known as the *lift coefficient* and

the *drag coefficient* of the surface of the main plane at different angles to the line of flight.

From the *ratio* of these coefficients and the size of the wing surface the resultant center of pressure can be calculated; or a curve can be plotted from them and

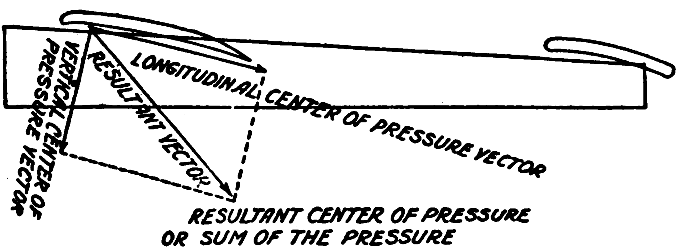

FIG. 11.—DIAGRAM SHOWING THE RESULTANT CENTER OF PRESSURE

the resultant center of pressure can be easily picked out without calculation.

How the Propeller Works.—In the beginning of this chapter I said that flying machines with beating wings had never been successful and that aëroplanes were fashioned after the outstretched wings of soaring birds.

While the above is strictly a true statement of fact the propeller which drives the machine through the air is really a great pair of wings that beat the air and send the aëroplane forward. About the only difference between a beating wing and a propeller blade is that the former works to and fro on a pinion and *beats* the

air on its down stroke only, while the propeller *revolves* and its blades beat the air all the time. It is man's improvement on Nature.

The propeller blades strike the air so hard the latter acts almost as a solid at the instant of impact, and

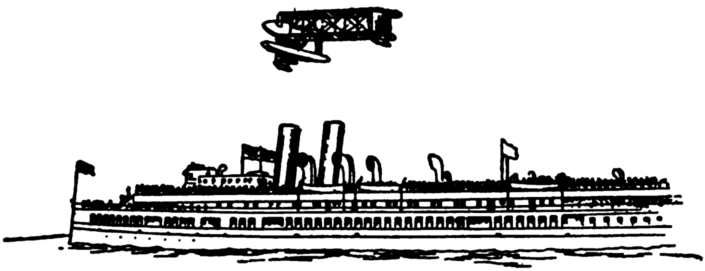

FIG. 12.—THE WAY OF A MACHINE IN THE AIR
A Burgess-Dunne seaplane flying over New York Harbor

this drives the machine to which the propeller is fixed along through the air at a goodly clip.

How Speed Helps Flight.—Throw a smooth, flat stone close to and over the surface of a lake of still water, and when it hits you will see it bounce into the air and skip and then hit, bounce and skip two or three times again before it sinks.

The stone is heavier than the water, but its speed is such that when it hits the water the inertia of the latter makes it act like an *elastic solid* and this reacts on the stone, which is forced back into the air.

In the early days of railroading an engineer would drive his engine at full speed over a bridge that was

weakened by the washing away of a pier, and get across safely, whereas if he had run over it slowly engine and all would have gone through it and fallen into the river below.

The speed of a body acts on the air in the same way as it does on a stone when it strikes the water, or a skater on thin ice, or on an engine crossing a weak bridge, all of which goes to show that even a table will sail through the air if it is going fast enough.

Langley, who made the first model aëroplane that flew as a self-respecting model should fly, performed the following interesting experiment to show how speed acts on the resistance of the air.

He had a whirling apparatus built that had a great arm 100 feet long. This was set up out of doors and the arm was driven by a steam engine at speeds up to 70 miles an hour. On the end of the arm he hooked a spring scale and to the scale he fastened a brass plate which weighed a pound.

When the arm was whirled round at a high speed, instead of the scale showing that the air resistance had increased the pull of the brass plate to *more than a pound,* as might be expected, it showed a pull of *less than one ounce.*

This experiment proved that if an object moves at a speed that is high enough the pull of gravity is greatly lessened and that speed is the all-necessary thing to make an aëroplane fly.

CHAPTER III

HOW AN AËROPLANE IS BUILT

If you have ever seen an aëroplane fly your interest in aviation will be fixed for all time; or, better, should you be fortunate enough to make a flight you will never be satisfied until you become a licensed pilot either for the pleasure or the profit of the thing, or both.

An aëroplane is a machine of mighty consequence, and for this reason it must be designed with all due consideration of the laws of *aëro-dynamics,* that is, the forces that produce motion in the air, built with a *high safety factor* of strength, *controlled* with devices that are simple and effective and *powered* with engines that are tried and true.

Types of Aëroplanes.—There are two general types of machines built at the present time and these are (1) the *monoplane* shown in Fig. 13, and (2) the *biplane,* as shown in Fig. 14.

Again both of these types can be divided into two classes, namely, (1) those with propellers in front, or *tractors* as they are called, see Fig. 15, and (2) those with propellers set back of the main planes or *pushers* as they are known, as shown in Fig. 16.

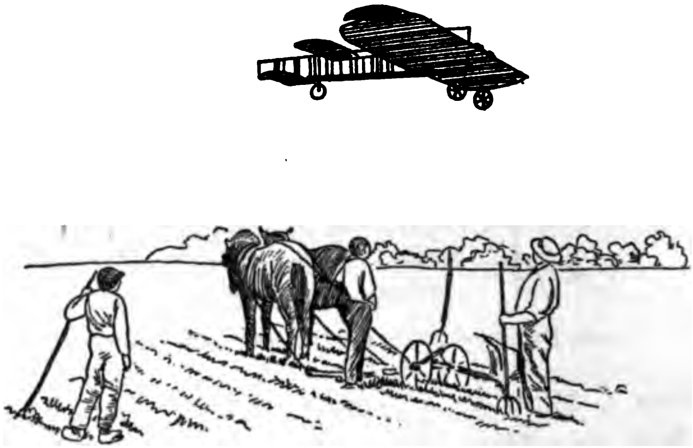

Fig. 13.—The Monoplane of Bleriot Passing over a Farm During a Cross Country Flight

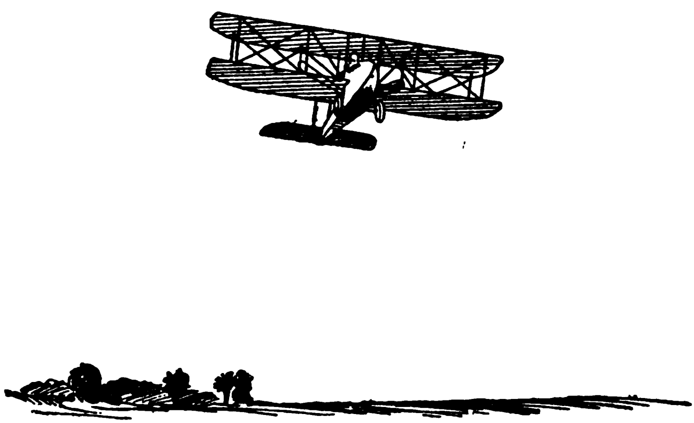

Fig. 14.—Latest Wright Flier at Mineola, Long Island

These classes can again be subdivided into (1) machines that are fitted with skids, or wheels, or both, which are *aëroplanes* proper as shown in Fig. 17; (2)

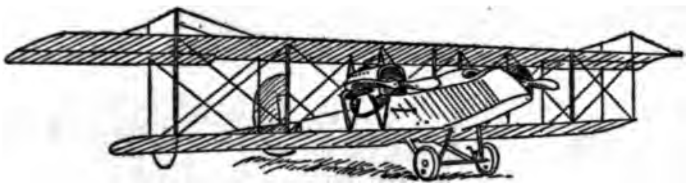

FIG. 15.—THE CURTISS TWIN MILITARY TRACTOR

those that are fitted with *pontoons,* or floats, for rising from and alighting on the water, called *seaplanes,* but formerly termed *hydroplanes* or *hydroaëroplanes,* see

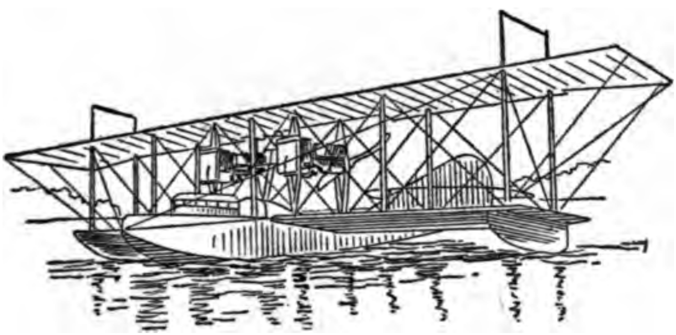

FIG. 16.—A PUSHER TWIN BIPLANE FLYING BOAT OF THE TRANSATLANTIC TYPE

Fig. 16, and (3) those that are fitted with *hulls* for skimming over and soaring above the water, or *airboats,* or *flying boats,* see Fig. 18, as they are now known.

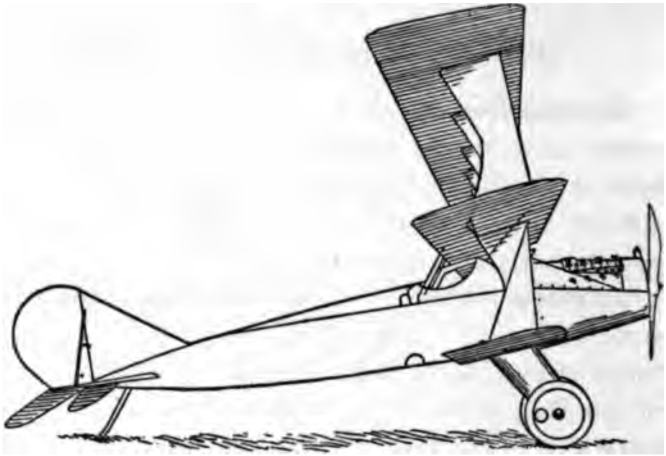

FIG. 17.—A CURTISS TRACTOR TRIPLANE

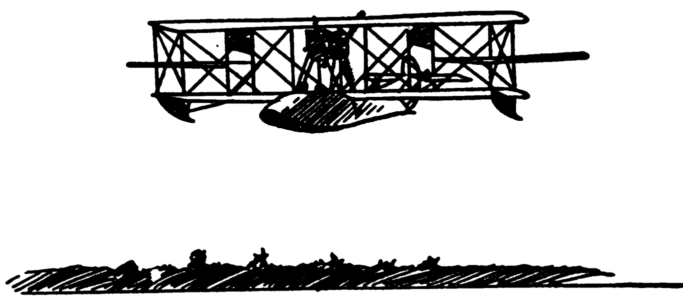

FIG. 18.—A CURTISS FLYING BOAT

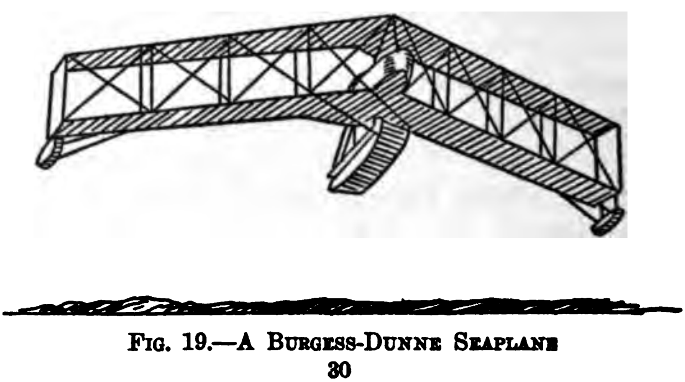

FIG. 19.—A BURGESS-DUNNE SEAPLANE

General Design.—The design of aëroplanes differs widely with various makers, but they all aim at the same goal and that is to get the greatest strength, the lightest weight and the highest power with the best *natural balance,* or *inherent stability,* as it is called.

And these efforts to unite all of the above good features in a single machine have resulted in the many forms of monoplanes of the Bleriot [1] type and biplanes of the Wright type together with numerous combinations of tails and *ailerons,* elevators and rudders, controls, engines and propellers.

General Construction.—To look an aëroplane over for the first time it does not strike one that there is a great deal to it but for a machine to hold together under the tremendous strains to which it is subjected when flying even in calm weather, and once in awhile in alighting, it must be built with all the skill and cunning that human ingenuity can put upon it.

To this end all the wood and metal that is used must be selected with care, and each piece tested to guard against flaws which in the early history of flying were the cause of frequent accidents.

Bodies, Frames and Hulls: *The Bodies of Monoplanes.*—The bodies, or *fuselages,* as they used to be called, of monoplanes are long and slim, but they are given slightly different shapes and are made of many kinds of material.

[1] Bleriot was the first aviator to make the monoplane famous and he did it by flying across the English Channel.

An early body was built up of three *longerons*, that is, long bars held in place with crossed braces. Other and later designs took on the shape of a bird's body, a fish or sometimes a racing shell. In the Bleriot—which was the first monoplane—and the *taube* [1]—an early German warplane—the bodies were made of four *longerons*, coming almost to a point at the rear end. Some of the bodies have masts built up in them near the front end to hold the guy wires in place that support the main planes.

Bodies are made of a variety of materials, including cedar, ash and Honduras mahogany, and are braced with aluminum, wood struts or steel wire. Steel tubing is also used for the frame, and these are cross-braced with wire, while bamboo joined together with steel tees, cross-pieces and fittings has been tried, but without much success.

Where the framework is exposed it is often covered with aluminum paint, but bodies should have their sides covered with fabric to lessen the head resistance.

The Frame of Biplanes.—Some biplanes use the frames of the planes with *outriggers* for supporting the *auxiliary* planes and some are fitted with bodies like monoplanes. The Burgess-Dunne biplane has a body like a boat, but owing to the V shape of the main-planes, or *wings*, as they are sometimes called, there is no body and no outriggers. It is shown in Fig. 19.

[1] The word *taube* means dove in German. It is so called because it looks like a dove.

In all American biplanes the frames are made of wood, but there are a few foreign-made machines that have frames built of steel tubing. The Wright machine is built of clear spruce and ash, and all parts that are not otherwise covered are painted over with an *aluminum mixture.* The frame of the Curtiss biplane is also made of ash and spruce and is cross-wired in three directions.

Hulls for Flying Boats.—These *hulls* are closed water-tight boats and on which are mounted the other parts of the machines.

In the Wright *airboat* the hull is quite short, but it has been given a large *freeboard,* as the part between the water-line and the *gun-wales* is called, and it also has a good depth and a wide beam to make it seaworthy.

The hull of a Curtiss flying boat is built of mahogany. The framework is made of closely spaced ash strips, and the forward section has a double bottom with a couple of layers of *Sea Island* cotton set in glue in between them. The planking is made of spruce, and all parts are fastened with brass and copper screws and rivets.

The Wings of Monoplanes.—The making of wings for monoplanes is not an easy matter, for there is no way to brace them except by guy wires.

The *ribs* of the wings are usually made in one of two ways, and these are (1) by using a pair of ash slats fastened to the spars, as shown at A in Fig. 20 and

(2) a single piece of wood which is sometimes forced into a steel tube.

The greatest curvature of the wings, that is, the curve that the ribs are given, is usually near the front, or *leading edge,* as shown at B in Fig. 21, but some wings

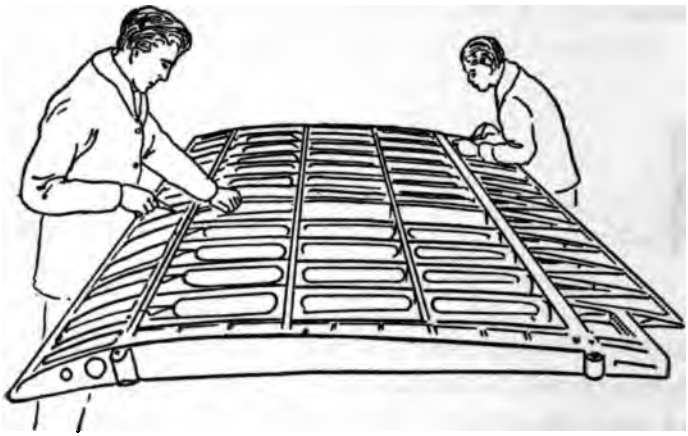

FIG. 20.—HOW THE MAIN PLANES ARE MADE

are made with an even curve, and they seem to work about as well as those of more scientific design. At any rate the curve should be about the width of the wing. But what affects the flying more than the exact curvature of the wing, or *camber* as it is called, is the *angle* at which the wings set on the body— that is, the *angle of incidence.*[1]

The entire framework of some wings is made of steel tubes whose joints are welded together. In the earlier

[1] The relation of the wing to the fuselage to which it is fixed.

monoplanes the wings were set at a slight V, or *dihedral angle,* but in the more recent machines they are made straight from end to end. The German aëroplane designers used to give the main planes the shape of a bird's outstretched wings, as in the *taube* monoplane shown in Fig. 22.

The wings are often covered on both sides with silk

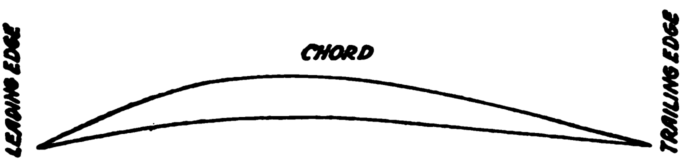

FIG. 21.—THE CURVE OF AN AIRPLANE WING

and this is sometimes doubled, but more frequently *rubberized fabric* is used, that is, linen that is either coated or *impregnated* with rubber. The *trailing edges,* that is the rear edges, of the wings are sometimes made so that they can be *warped,* that is curved more or less, but as this has to do with the control of the machine it will be taken up in the next chapter.

The Wings of Biplanes.—In the first biplane of the Wrights' the frame of the wings, including the ribs, were made of wood, and this material is still used in their machines.

The wings usually set square one above the other, but in some aëroplanes they are *staggered,* that is, the upper wing sets out a little ahead of the lower wing.

In the Burgess-Dunne biplane the wings take on a V shape, upward, sidewise and endlong, as shown in Fig. 19.

Wood is chiefly used in the construction of wing frames in this country, while in Europe main planes are built in which steel tubes are used for the frames

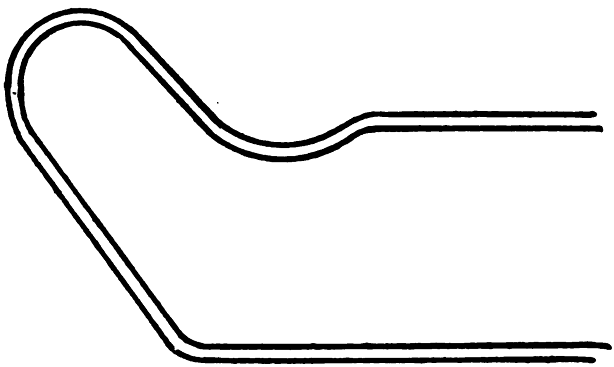

FIG. 22.—A TAUBE MONOPLANE WING

and aluminum for the ribs. Bamboo has been used for both frames and ribs, but it has not met with much favor.

The frames of the Curtiss wings are made of spruce with ash-ribs cross-stayed with piano wire and covered with unbleached linen treated with a rubber preparation.

The Goodyear Tire and Rubber Company makes a special fabric for covering wings that is *impregnated* with rubber. It weighs about 7¾ ounces per square

yard, is 39 inches wide, its strength is 75 pounds to the square inch and its cost is $1.35 per running yard.[1]

To test aëroplane fabric soak a sample in salt water, and if the fabric is varnished it will soften it. Then dry the sample in the sun, and if it neither stretches nor shrinks you will know that it is O.K., and you will be on the safe side in using it.

The fabric is fastened to the wings either by tacking, or lacing it to the *front span* and the trailing edge and tacking it to the rear span and to the ribs. The wings of biplanes are sometimes made rigid so that they can be *warped*, and this latter kind will be described in the next chapter.

There is a standard steel wire tinned on the outside that is made by the John A. Roebling's Sons Company, of Trenton, N. J., especially for aëroplane work. It is called *aviation wire* and it can be had in all sizes from No. 4, which is $\frac{13}{64}$ inch in diameter with a *minimum breaking strain* of 6,700 pounds to the inch, to No. 20, which is $\frac{1}{32}$ inch in diameter with a minimum breaking strain of 225 pounds to the inch.

To find the breaking strain of a wire a piece 15 inches long is put between the jaws of a standard testing machine so that a length of 10 inches of the wire is clear between them. The *load* is then applied by means of a handle at a speed of about 1 inch per minute.

[1] Prices given in this book are subject to change on account of the war.

There are other tests for the *torsion,* that is, the twist of the wire, and also for bending. A good ferrule for making wire connections is shown at A, B and C in Fig. 23.

The Elevation Planes of Monoplanes.—Nearly all monoplanes have a small three-cornered surface set at the rear end of the body, though a few machines

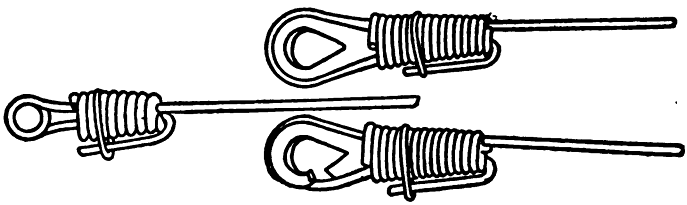

FIG. 23.—FERRULES FOR WIRE CONNECTIONS

have been built without *elevators,* or *elevating rudders,* as the *elevation planes* are sometimes called.

Other monoplanes have a pair of *flaps* that are hinged to a horizontal span which in turn is secured to the *rearmast,* or *sternpost,* as in the *taube* monoplane, and finally there are spreading tails, also like the *taube,* in which the trailing edge can be moved up and down. From the above it will be seen that the elevating planes are made rigid, or hinged or flexible, when they can be warped, as the designer dictates, all of which is explained in the next chapter.

The Elevation Planes of Biplanes.—The elevation rudders of biplanes are about the same as those

used on monoplanes, but they are sometimes set in front of the main planes, as in the early Wright machines, and they are usually mounted in pairs.

When fixed to the rear of the machine they are sometimes made in the shape of a cross, as shown in the next chapter, the vertical surface being used for a direction rudder. In other biplanes they are made like the sides of a box, also shown in the next chapter; by moving them up and down the machine is made to rise and fall and by moving them from side to side the machine is turned to the right or left. The Wright machine is now fitted with a single elevating plane at the rear.

The Direction Rudders of Monoplanes.—Direction planes are of course always set in a vertical position. Some rudders are made with one plane only, while others are formed of two surfaces, and these are either *oval-shaped* or *rectangular* in form. They are always set on the rear end of the body.

The Direction Rudders of Biplanes.—In some biplanes the direction rudders are placed above the elevation planes; in others they are set under the tail, but the common practice is to set the elevation planes at right angles to and crossing the direction rudder. While the usual position of the rudders is at the rear of the wings sometimes a small one is set in front and a large one is placed behind. When the rudders are set at the back they are fastened to the rear mast of the fuselage or between the ends of the outriggers.

Fins or Keels of Monoplanes.—Monoplanes have been made without keels, or fins, as they are more often called, but when they are used they are set near the rear end of the machine.

Fins, or keels, may be placed in either a vertical or a horizontal position. When set vertically they are used to give the machine sidewise balance, and when set horizontally they add to the lengthwise stability of it.

Fins or Keels of Biplanes.—The 1909 Wright machine had no fin or keel, the sidewise balance being obtained by the vertical planes of the direction rudders. In their more recent types of biplanes keels have been added which can be moved to and fro by the pilot to get a better balance. In many machines the ends of the *plane cell,* as the pair of wings of a biplane is called, or partitions between the wings, are covered, and these vertical surfaces act as fins, or keels, and serve to maintain the lateral balance.

The Running Gear of Monoplanes.—The framework on which the body rests and to which the wheels are fixed, also called the *chassis,* or mounting, takes on many forms. For instance landing gears have been made that are perfectly rigid, but those that have springs of one kind or another to absorb the shock of the machine when it is brought to the earth are mostly used; a good gear is shown in Fig. 24.

As good a landing gear as any is to have a pair of wheels fastened to the chassis, which is itself made of

a pair of long skids, and mounted in front of and a little under the wings; and then there should be a smaller skid in the rear near the end of the body; or a small wheel can be used instead of the rear skid. Again a small wheel is often set in front of the main pair of wheels, making four wheels. Another machine has a

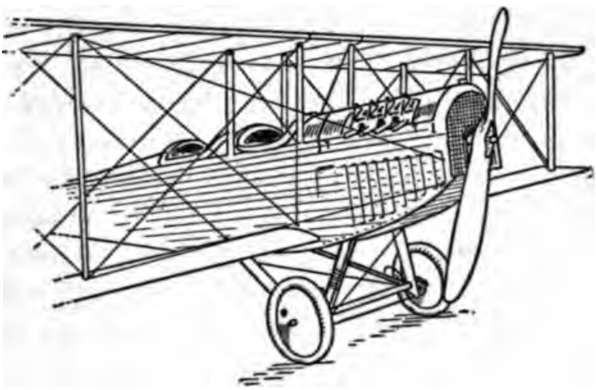

FIG. 24.—A LANDING GEAR

large wheel mounted to the base of the forward mast, while the tip of each wing is fitted with a small wheel.

The Running Gear of Biplanes.—The first Wright machines had no wheels, but a great pair of skids that looked very like the runners of a giant bob-sled took their place. When a start was to be made the biplane had to be hoisted by a derrick and set on a little car which ran on a rail laid on the ground.

The running gears of biplanes are about the same as

those used with monoplanes. Wood and steel tubes are employed for the frames, and pneumatic rubber tire wheels are fitted to them.

The tires for the wheels, see Fig. 25, are made with inner tubes like ordinary automobile tires, but they are smaller and much stronger. They come in several sizes,

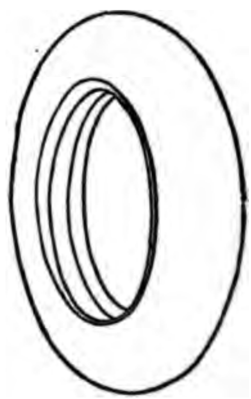

FIG. 25.—A PNEUMATIC TIRE FOR AËROPLANES

weights and carrying capacities; the 26 x 3-inch tires have a carrying capacity of 500 pounds and weigh 6½ pounds each; the 26 x 4-inch tires have a carrying capacity of 800 pounds and weigh 7½ pounds each, and the 26 x 5 tires have a carrying capacity of 1,200 pounds and weigh 15 pounds.

They are built up of cords, that is, they are formed of layer upon layer of fine cord, with all of the cords in each layer running in the same direction with every other

layer laid across the ones between. This cord construction helps to make an easy and quick getaway, and besides it takes up the jars and jolts of heavy landing.

Floats for Seaplanes.—Floats are made of wood, or metal, or both wood and metal combined. The specifications for seaplanes built for the U. S. Army call for two main floats and such others as may be needed.

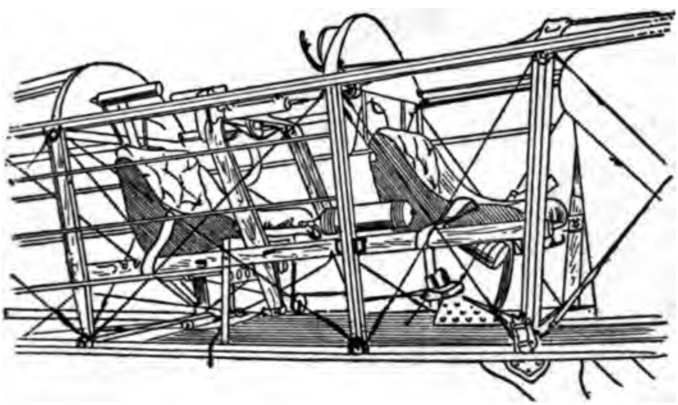

FIG. 26.—SEATING SECTION IN A STANDARD AËRO COMPANY'S AËROPLANE

Each main float must have not less than four watertight compartments, and each compartment must have a convenient means for completely draining it at the bottom.

The floats should be readily detachable, and great care must be taken to insure the whole hull of the float being strong. Floats made of all metal are considered

the best, and hardwood runners should be fitted to them to protect them while on the beach.

Other Parts of Monoplanes.—The seat, or seats, are usually placed in the body, as shown in Fig. 26.

The Nacelle.—The best arrangement for the seats, controls, etc., is to enclose them in a spindle-shaped body called a *nacelle* of sheet metal and hang them by rigid supports in the frame between the longerons.

Other Parts of Biplanes.—In the early Wright machines and in the Wright Model B of today the seats were and are placed on the front edge of the lower plane so that the aviator's feet and those of the passenger rest on a cross-brace of the skids. In the early Curtiss machines the seat was set on the chassis in front and below the main plane.

The controls for steering and balancing aëroplanes and the power plants which include the engines and propellers for driving them will be taken up in the following chapters.

CHAPTER IV

HOW AN AËROPLANE IS BALANCED

A good deal has been said about the *stability,* or *balance,* of aëroplanes, but none of the man-carrying machines have an *inherent,* or *natural,* balance to any great extent.

By this I mean that if an aëroplane should be left to fly by itself it would soon lose its balance and topple over just as an automobile if left to run by itself would soon be ditched. The purpose, then, of a pilot of an aëroplane is practically the same as that of the driver of a motor car, and that is to keep the machine under control.

Two Kinds of Balance.—You will remember that aëroplanes must have two kinds of balance to keep them in the air, and these are (1) *longitudinal,* or *endlong,* balance, and (2) *transverse,* or *sidewise* balance. And you will also remember that to keep the machine balanced lengthwise is not a very hard thing to do, but to keep it balanced sidewise is not quite so simple a matter.

Ways of Balancing an Aëroplane.—There are three ways to keep an aëroplane balanced when it is

flying, and these are (1) by the skillful handling of the planes by the pilot, or *manual balance*, or *controlled stability*, as it is called, (2) by giving the wings a certain shape and placing them and the rear planes, when these are used,[1] to the best advantage, which gives it a certain *inherent stability*, that is, a natural or self-balance, and (3) by using pendulums, gyroscopes and the like, which *automatically balances* the machine, and these mechanical devices are called *automatic stabilizers*.

What Manual Balance Means.—All kinds of monoplanes and biplanes, however well they are fitted with fins and other vertical surfaces and with tails and other horizontal planes, must be balanced as well as steered by the pilot through levers or wheels or footbars, which move these surfaces up and down and from one side to the other.

In this way an aëroplane is just about the same as a bicycle. If you give a bicycle a shove it will not run far before it will lose its balance and fall over. If a rider is in the seat who does not know the knack of balancing the machine it will tumble even quicker than before, but in either case it will keep up pretty well if it has enough speed and a ten-acre field to run in.

But once the bicyclist has learned the *how of it* he can ride without holding on to the handle bars and do all manner of tricks on the machine until it verily seems as if there was no such force as gravity and that the

[1] The Burgess-Dunne aëroplane has no rear planes.

wheel could not be made to take any other position than a plumb one. And the faster it goes the better it keeps its balance.

It's the same way with an aëroplane and a pilot, only a little more so. It is the pilot who keeps the machine balanced endlong less or more and sidewise more or less. The endlong balance has to be taken care of when the aëroplane is going up, for then its longitudinal balance is poorer than at any other time.

Its lengthwise balance is pretty good when its path of flight is horizontal, and, curiously as it may seem, it is at its best when it is gliding toward the earth at its natural gliding angle, or *volplaning* as it is called.

But it takes some skill to bring it to the proper angle with its nose down when the motor suddenly stops, because the machine loses *headway*, and this tends to make it fall to the earth tail first. As long as the *power plant* drives the machine through the air at a high enough speed there is little chance of its diving or dropping if it is handled right.

To keep the aëroplane balanced sidewise though is where the pilot gets in his fine work, for when a gust of wind strikes it broadside on, or when it is turned too sharp and begins to *side-slip* as though it was on a steep bank it is always in danger of upsetting. Now there are two kinds of side-slipping, and these are (1) *outward* and (2) *inward*, and either of them is likely to result in a *spin*. The way to prevent a machine from

spinning and the way to right it when it begins to spin will be explained in Chapter VI.

Even when flying straight ahead in calm weather it is never safe for the pilot to take his hands off of the controls and let the machine fly by itself. But when all is said it is by the knowledge and skillful operation of the aëroplane that the name of a pilot is written on the roll of those accounted best and who are still among the living fliers.

How Manual Balance Is Had.—When a bicyclist is on a wheel he balances both it and himself by moving his body from one side to the other in the opposite direction to that which the machine tends to fall.

This same scheme of balancing is used when flying with a *glider,*[1] but with an aëroplane weighing half a ton or so the shifting weight of the pilot in his seat would have a very small effect on restoring the *equilibrium,* as righting its balance is called, of the machine, and besides it would be hard to do it this way in practice.

So instead of the pilot balancing his aëroplane in this rude fashion he does it in an easier, quicker and more certain manner, and this is by changing the positions of the vertical and horizontal surfaces, or planes.

Ways of Manual Balancing.—The manual balance of an aëroplane lengthwise is done in a number of ways such as (1) the use of planes, or *flaps,* in front of

[1] A glider is a young aëroplane without the power plant.

or at the rear end of the machine or both, and (2) by warping the *trailing* edge of the tail. The sidewise balance is obtained (1) by warping the wings and (2) by the use of *ailerons* and wing-tips, as the pictures in this chapter show.

How Lengthwise Balance Is Had.—When an aëroplane is flying the air pressure against the wing, or

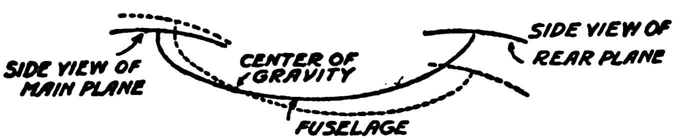

FIG. 27.—DIAGRAM SHOWING LENGTHWISE BALANCE

When the wind raises the main plane the machine swings on its center of gravity and the rear plane is lowered as shown by the dotted lines. This makes the main plane and the rear plane offer a greater resistance; this acts as a brake and slows down the machine, and since the front is the heaviest it then drops down. In this way *longitudinal stability* is had.

main plane, raises the latter, and this makes the machine swing on its center of gravity, as shown by the crossing lines in Fig. 27.

This makes the main plane and the rear plane offer a larger spread of surface to the wind; thus they act as a brake and slow down the machine, and since the front is the heaviest it then, of course, drops. It is in this way that longitudinal stability is had.

Since it is easy to control the lengthwise balance of a machine the elevating planes can be moved or the tail warped by connecting them with a foot-bar, as shown

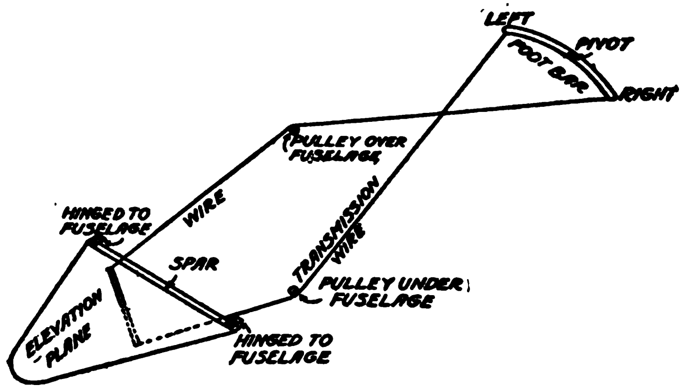

FIG. 28.—FOOT BAR CONTROL FOR ELEVATING PLANE

When the right side of the bar is pushed forward the elevated plane is raised; when the left side is pushed the plane is lowered.

in Fig. 28, or they can, of course, be worked by cables connected to a lever, or to a steering wheel.

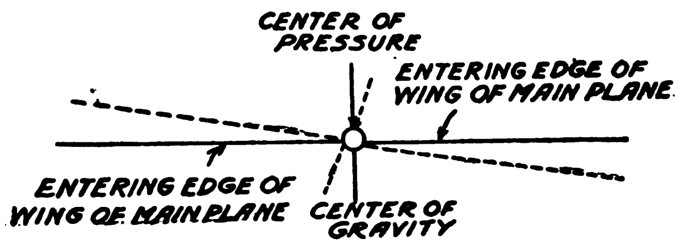

FIG. 29.—DIAGRAM SHOWING SIDEWISE BALANCE

When one wing of the aëroplane begins to tilt down the other wing of course tilts up. This makes the wing surface offered to the force of the air smaller and so shifts the center of pressure toward the down side as shown by the dotted lines. In turn this action tends to bring the planes back to a level position.

How Sidewise Balance Is Had.—When one wing of the aëroplane begins to tilt *down* the other wing must of necessity tilt up, as shown in the diagram Fig. 29. This makes the surface offered to the force

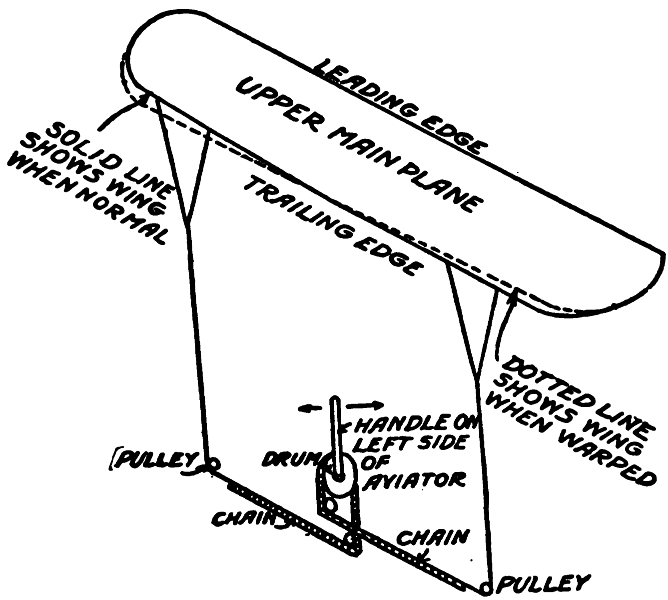

FIG. 30.—HANDLE AND DRUM CONTROL OF WARPING THE WINGS

of the air smaller and shifts the center of pressure toward the down side, as shown by the dotted lines. This action in turn tends to bring the planes back to a level position, or even keel as it is called.

Wing Warping.—To further help this balance the

wings can be *warped,* which means that one of the tips of the trailing edge of the main plane is raised up and the other tip of the trailing edge is pulled down at the same time by the pilot.

In this way one of the wings is given a larger surface for the air to lift on, and the other wing is given

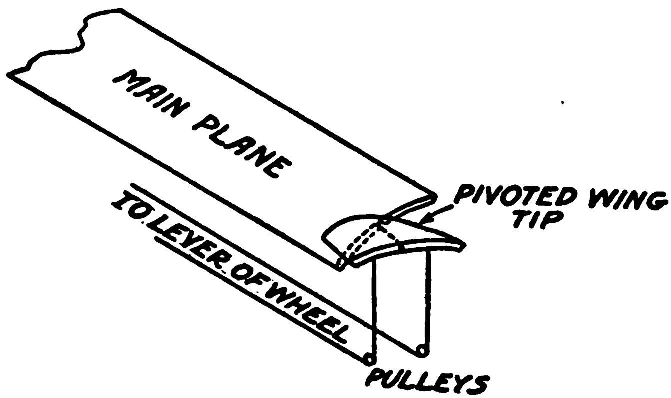

FIG. 31.—PIVOTED WING TIPS AND METHOD OF CONTROL

a proportionately smaller surface. When a gust of wind strikes the machine and the wing that is struck is made smaller by warping it eases up the pressure of the air, while the wing on the other side is made larger so that the air acts on it with greater force and together they equalize the air pressure and so right the position of the machine.

The warping is done by a cable connected with the trailing edge of each of the wings in a monoplane and

to each edge of the upper main plane of a biplane; the cables run over pulleys, the ends being fastened to or worked by a wheel, or a lever, as shown in Fig. 30, which is the original Wright system of control.

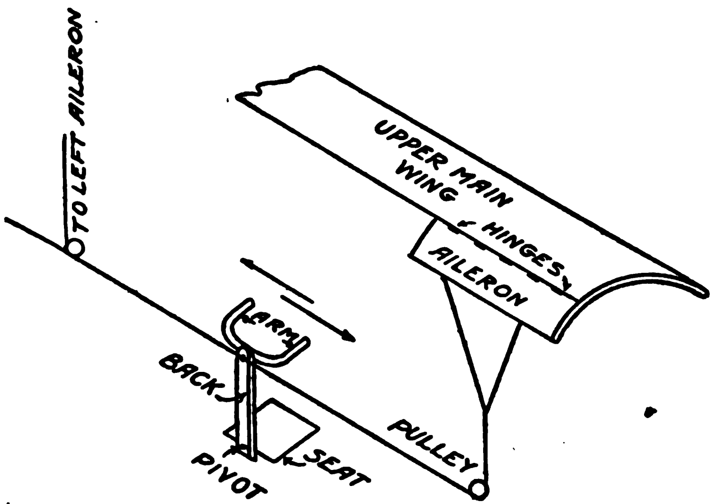

FIG. 32.—THE CURTISS CONTROL OF AILERONS
When the right wing drops the pilot naturally leans over toward the left; this pulls the right aileron down and the aëroplane straightens up.

Where *wing-tips* are used they are pivoted in their centers to the ends of the main planes, as shown in Fig. 31, and these are controlled in the same way as warped wings.

The Use of Ailerons.—Another way to straighten up a tilting aëroplane is to use *ailerons,* or wing tips that

are hinged to the trailing edges of the main plane, as shown in Fig. 32, or they can be hinged between the wings of a biplane.

These *ailerons,* or *balancing* planes, as they are sometimes called, are simpler to make and easier to work than warping the wings; but they are not as good a scheme as wing warping, for the reason that they tend to slow down the speed of the machine if they are tilted too much, while if they are hung between the wings of a biplane much of the effect is lost.

Other schemes so that the pilot can balance his machine have been tried, such as sliding panels in the wings, by vertical surfaces on or between the planes, but wing warping and ailerons give the best results.

How the Direction Controls Are Worked.— Besides the lengthwise and sidewise balancing of an aëroplane to keep it right side up the pilot has to steer it up and down as well as to the right and left.

The elevation and the direction of an aëroplane is caused, as you know, by horizontal planes and vertical surfaces, called *elevators* and *rudders* respectively, and these are either hinged or pivoted to the machine so that they can be raised or lowered, or moved from side to side.

To control the movements of the elevators they are connected with levers, steering wheels or foot-bars by means of wires, or cables, running over pulleys wherever the line of direction is changed.

The Elevating Planes.—These are rudders for steering up and down as well as planes for balancing the aëroplane lengthwise. The pilot knows by the *feel* of the elevating planes whether the pressure of the air is

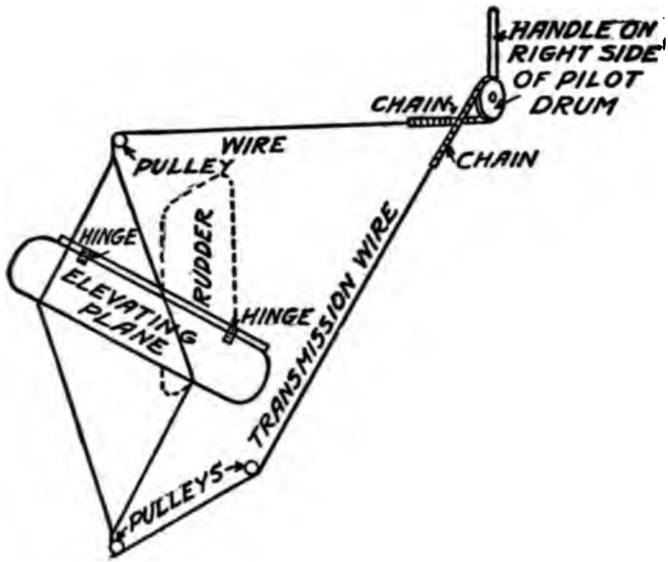

FIG. 33.—EARLY WRIGHT ELEVATOR CONTROL
Dotted line shows the rudder

too much or too little and he pulls the lever, turns the wheel, or pushes on the foot-bar until the machine is flying along the aërial road he wants it to go.

All sorts of controls have been used for working the elevation planes, but the steering wheel gives the best results just as it has proved the most satisfactory con-

trol for automobiles. Fig. 33 shows the original Wright handle control and Fig. 34 shows an early wheel control.

The Direction Rudder.—The vertical plane, or planes, that are used for steering the aëroplane to the right or left are either hinged to the stern post or are

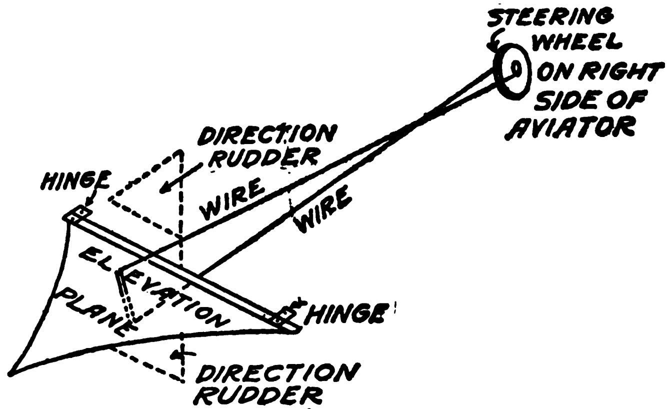

FIG. 34.—STEERING WHEEL CONTROL OF AN ELEVATION PLANE

swung from side to side like the rudder of a boat, or they can be fixed tightly to it and the rear edge *flexed*, that is, bent from one side to the other. In biplanes where outriggers are used the direction rudders are usually pivoted between them.

The direction rudder is often worked by means of a foot-bar, though sometimes by a lever, or the steering wheel. These rudders, like the elevating planes, are connected to the controls with either wires

or cables, which should always be in *duplicate,* that is, two should be used instead of one so that should one of them break there can be no accident. Fig. 35 shows a rudder with a foot-bar control.

Since the rudder caused the aëroplane to *nose down* on

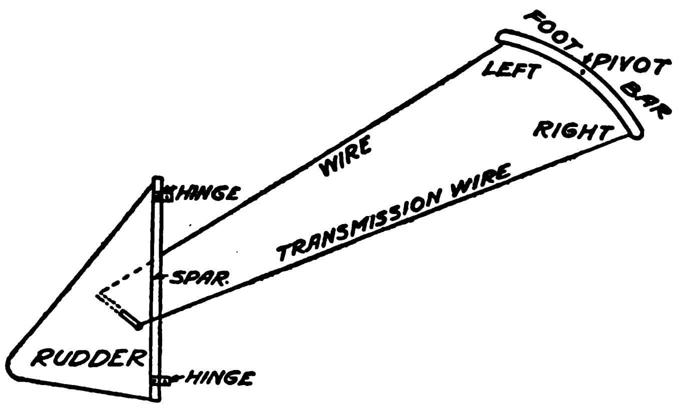

FIG. 35.—FOOT BAR CONTROL OF AN ELEVATION PLANE

the side to which it is turned the first Wright machines had the wires which warped the wings fastened to the same lever that worked the rudder, and in this way the machine was kept on an even keel. The scheme is shown in Fig. 36.

How a One-piece Elevator and Rudder Is Worked.—When the tail of a machine is made of either a *box-cell,* or in the form of a cross, the horizontal surfaces are used for elevating planes and the vertical surfaces for direction rudders. To be able to move this one piece-

tail in any direction it is mounted on a ***universal joint*** which allows it to be tilted up and down for elevation or to be moved to and fro for steering a course. The Deperdussin control, or just *Dep* for short, which is in general use at the present time, is shown in Fig. 37.

When the steering post is pushed or pulled in the

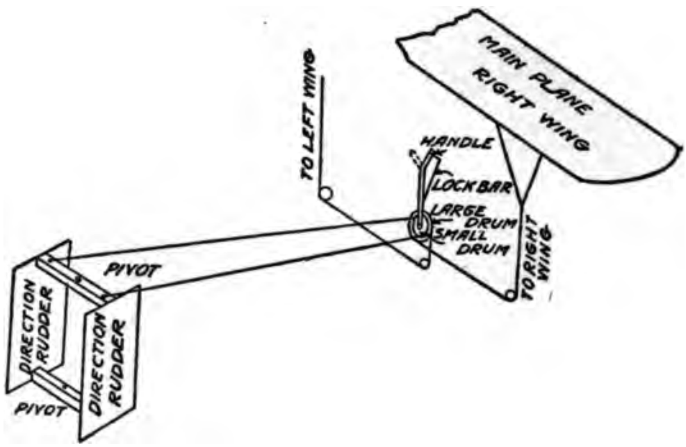

FIG. 36.—THE WRIGHT RUDDER AND WING WARPING CONTROL
The lever warps the wings at the same time that it works the direction rudders. By *breaking the lever,* which means to move the handle, the rudder can be turned without warping the wings.

direction of the straight arrows the elevation planes are moved up and down, and when the steering wheel is turned in the direction of the curved arrows the direction rudders are moved from one side to the other.

Machines with Dual Controls.—Practically all aëro-

planes are fitted with a wheel control of the type just described, though the elevation planes and direction rudders are of different designs.

All machines in which pupils are taught to fly should and usually do have a *dual control,* that is, two steering

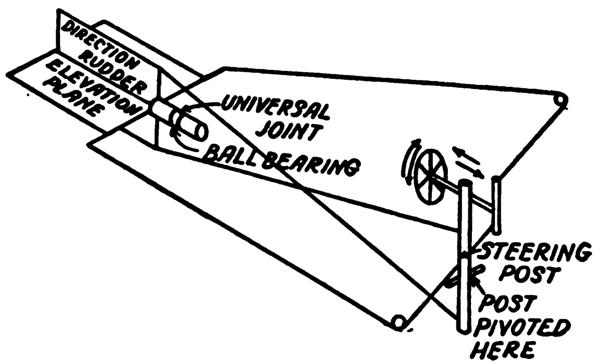

FIG. 37.—STANDARD DEP. (DEPERDUSSIN) CONTROL

wheels are fitted to the same steering post which works the elevation planes, and both wheels control the direction rudder through the same set of cables. By this arrangement the pilot is able to gradually give the actual control of the machine to his pupil just as fast as he is able to handle the machine under varying conditions of flight. The dual control is shown in Fig. 38.

A Self-Balanced Aëroplane.—There is only one machine on the market for which a natural balance is claimed, and this is the Burgess-Dunne.

Whatever *inherent-stability,* or self-balance, it pos-

sesses is attributed chiefly to the arrangement of the main planes. The body is built like a boat, and on this are set a pair of biplanes joined together to form a V and when flying the tips of the wings dip a little.

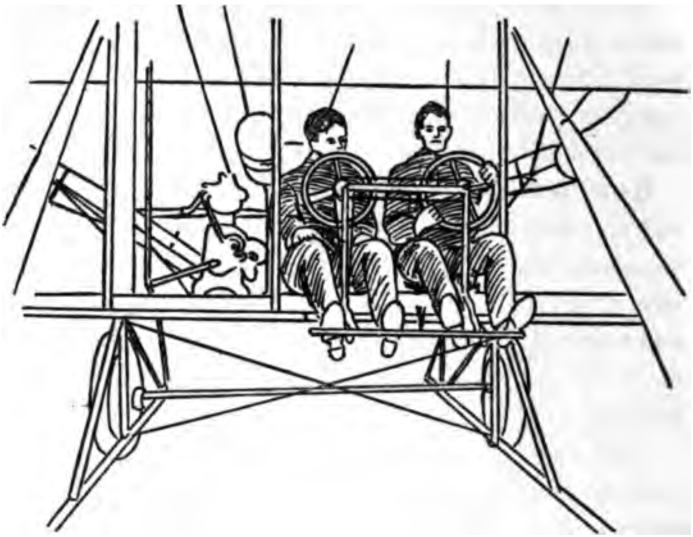

FIG. 38.—DUAL CONTROL IN AN OLD WRIGHT MODEL

The planes curve more at the center than at their tips, and this kind of *camber,* as the curvature of the wing is called, together with the V form of the planes, is said to equalize the changes of the center of pressure, and this gives the aëroplane a better natural balance than in machines built along orthodox lines.

Each of the upper main planes has a corner cut out of the tip, and in this is fitted and to the spar is hinged

a small plane very much like an aileron. These small horizontal planes are used for both elevation and direction steering, and they are controlled by a pair of levers fixed on each side of the pilot's seat.

When an aëroplane is *inherently stable* it will not side-slip on a *steep-bank,* but will turn in proportion as it tilts, or *banks,* as it is called, and to get a self-righting machine many forms of planes have been used and not a few mechanical devices.

How Automatic Stability Is Had.—The third and last way to balance an aëroplane is to fit it with an *automatic stabilizer,* that is, to use some kind of a device which will warp the wings or work the ailerons automatically whenever the machine tilts one way or the other too much and so bring it back to its right position.

Pendulums have been used to secure this automatic control. The pendulum is pivoted to the bottom of the steering post and the *bob* is connected to the trailing edge of the main plane near the ends through a pair of small cables. When the machine tilts to the right the pendulum swings to the right and this warps the right end of the wing; the right wing having a smaller surface exposed to the air pressure than the left wing, the plane is pulled back into a safe position again. When the machine tilts to the left the operation is of course reversed. A pendulum stabilizer in its simplest form is shown in Fig. 39.

The Sperry Gyroscope Stabilizer.—This device makes use of the principles involved in a *gyroscope* (pronounced ji-ro-scope) and called just *gyro* for short.

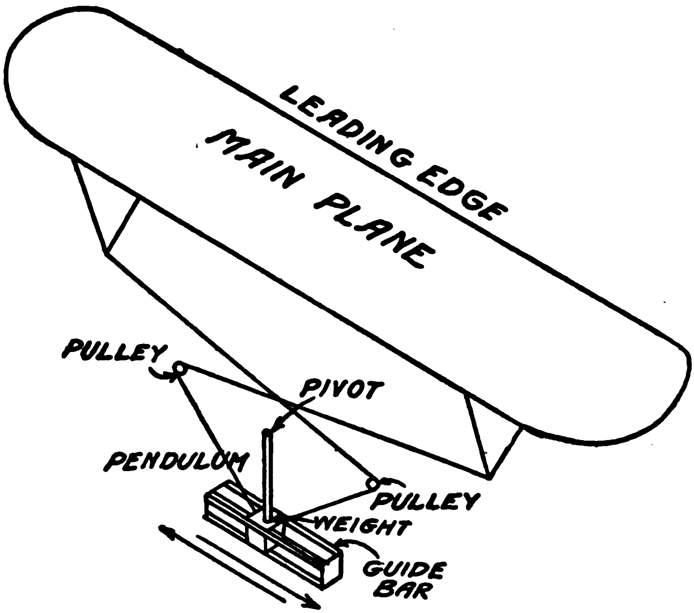

FIG. 39.—PENDULUM USED AS AN AUTOMATIC STABILIZER
The pendulum is pivoted to the bottom of the steering post; when it swings to the right the right wing is warped and when it swings to the left the left wing is warped.

Now a gyro, as you may or may not know, consists of a heavy wheel fixed to a spindle and pivoted in a ring so that it is free to turn, as shown in Fig. 40. When the wheel is made to spin at a high speed on a horizontal

axis, and you try to move the gyro out of the plane in which the wheel is spinning, you will find that it offers a very considerable resistance to the opposing force.

The Sperry stabilizer is formed of six units, and these are (1) the *gyro,* which really consists of four

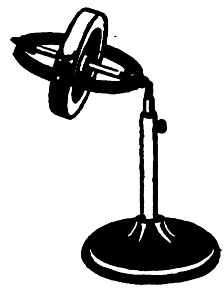

FIG. 40.—A TOY GYROSCOPE

smaller gyroscopes arranged in pairs; these gyros always maintain their horizontal mounting, (2) the *generator unit,* which is driven by the engine and supplies alternating current to spin the gyros and work the *impressor system* and *magnetic clutches;* (3) the *servo motor unit,* which operates the control area of the aëroplane; (4) the *hand control unit* for handling the aëroplane at will by means of the stabilizer equipment; (5) the *anemometer unit,* which is a single pole, single throw switch, and (6) the *storage battery unit,* which is the source of direct current when the engine is stopped and is automatically cut in and out as required.

The *gyros* run at sufficient speed in virtue of their

own momentum to automatically control the aëroplane for 15 minutes after the engine stops. The gyro unit is shown in Fig. 41. These equipments are now in use on military aëroplanes of the English, French, Italian,

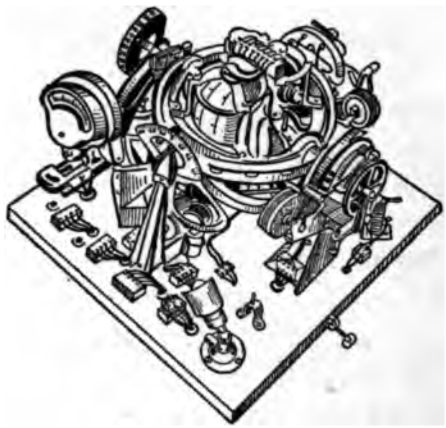

FIG. 41.—THE SPERRY GYRO STABILIZER

and Russian governments. It would take up too much space to describe the apparatus in detail, but a complete description of them can be had by addressing the Sperry Gyroscope Company, 126 Nassau Street, Brooklyn, New York.

CHAPTER V

HOW THE ENGINE WORKS

In the early days when Langley was making his first flying models he found the hardest part of it was to get an engine that was light enough and at the same time powerful enough to do the work required of it.

Some Early Aëroplane Engines.—And so all sorts of engines were tried out, including *steam engines; compressed air* and *carbonic acid gas engines,* and *electric motors* worked with *primary* and *storage batteries.* All of these different kinds of *power plants* were carefully tested and all were found wanting, for none of them would begin to lift its own weight as then made.

As the gasoline engine as we know it today had not been developed to a point where it could be used for driving aëroplanes in 1896, when Langley constructed his first model flying machine, or *aërodrome,* he designed and had a steam engine built which weighed only 26 ounces when finished and with its boiler it weighed only 7 pounds; this little engine *developed* 1½ horse power and drove its two propellers at the rate of about 1,000 revolutions per minute.

During the next five years after Langley's classic ex-

periments the gasoline motor, or *engine,* as it is now called in aviation, was improved until it was by far the most powerful engine of its weight made and it was with a four-cylinder, 25 horse-power engine of this kind, weighing 152 pounds, that the Wright Brothers made their first man-flights in 1903.

Requirements of Motive Power.—Since the gasoline engine is the only type of engine that is at once light and powerful enough to drive aëroplanes we will describe it here and no others, though it is not at all unlikely that the steam engine may be improved upon until it will be a better power plant for aëroplanes than the present gasoline motor.

The best motor for the aëroplane is the one that is the least apt to *stall,* that is, to stop suddenly, and indeed this seems to be the real fault of most of the motors used for aviation work, and after this comes light weight, power and efficiency. Boiled down, then, the first requirement for an aëroplane engine is (1) to be able to depend on it; after this all-important thing (2) it should be light in weight, but not so light that it is weak; next (3) it must have a lot of power even when running at comparatively low speeds; (4) it must not heat up; (5) it must not *back-fire;* (6) it must run smooth; (7) it must not vibrate; (8) it must be easy to start; (9) it must use a small amount of gasoline per horse power, and (10) it must be made of the fewest number of parts possible.

Kinds of Aëroplane Engines.—There are in general two kinds of gasoline engines, namely, (1) those in which the cylinders are fixed in place, and (2) those in which the cylinders revolve.

Of the fixed or stationary cylinder type there are engines which have 2, 3, 5, 6, 8, 10 and 12 cylinders; a few of these are *air-cooled,* but nearly all are *water-cooled.* In some engines the cylinders are set in a vertical line and in others they are placed in a V shape.

In the revolving cylinder type the engines usually have 7 or 9 cylinders, and these are always air-cooled.

How the Engine Works.—Now let us find out before we go any further just what the parts of a gasoline engine are and how it works, and so we'll start with the simplest kind of an engine, that is, one with a single cylinder.

A one-cylinder engine, or *one lunger,* as it is playfully called, is made up of (1) the *cylinder* and *piston,* the latter being coupled to a crank shaft by means of a *piston rod;* (2) a *carburetor* for mixing the gasoline with air and forming an explosive mixture, or *fuel mixture,* as it is called, which is drawn into the cylinder, and (3) a *magneto electric machine,* or *magneto,* as it is called for short, which makes a *high tension current,* that is, a current of high pressure, and this in turn makes the spark which explodes the gasoline mixture in the cylinder when (4) the *timer* closes the electric circuit.

From the diagrams shown at A, B, C and D in Fig. 42 you can easily follow out the working of an engine. The *cycle of operation*, as the successive movements of the piston are called, is this: suppose that the piston is at the upper end of the cylinder and that the inlet valve

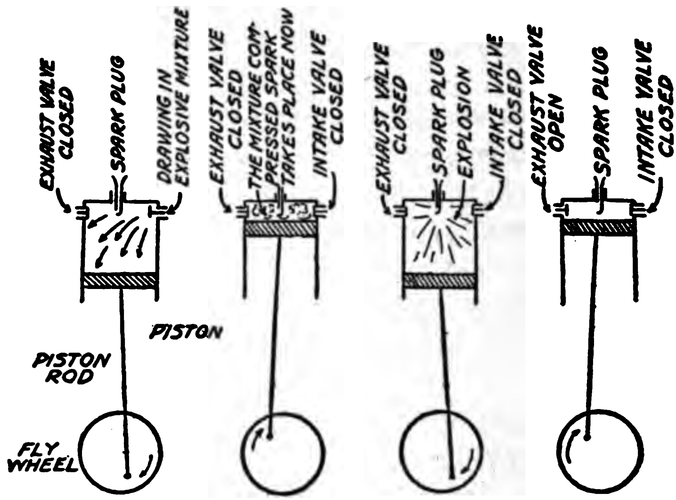

FIG. 42.—DIAGRAM OF A FOUR CYCLE ENGINE

that lets the fuel mixture into it has just opened, and the exhaust valve is closed.

Now when the fly-wheel is turned round to start the engine the piston, of course, travels down and it sucks the mixture into the cylinder, as shown at A. When the piston reaches the end of the down stroke the inlet valve is closed and the exhaust valve still stays closed, then as the wheel is turned on round the piston moves

up and this compresses the fuel mixture, as shown at B.

Just as the piston reaches the end of the up-stroke the spark circuit is closed by the *timer* and the current from the magneto makes a *jump-spark* across the gap of the spark-plug. This hot spark explodes the fuel mixture, the explosion drives the piston down with mighty force, and this turns the crank shaft round, as shown at C.

The instant the piston reaches the end of this down-stroke the exhaust valve opens, and as the piston moves up again the burnt gases are pushed out of the exhaust valve, as shown at D. Then this valve closes and the inlet valve is opened, as at A, when the cycle of operations starts all over again.

From this you will see that there is only one explosion to every four strokes of the piston and to every two complete revolutions of the shaft, hence it is called a *four-cycle* motor.

How the Carburetor Works.—The carburetor which mixes the gasoline with air to form the fuel mixture is usually the hardest part of an aëroplane power plant to understand, and yet you will find it quite simple if you will follow its operations step by step.[1]

To begin with, suppose you join a pipe to the bottom of a tank of gasoline and that the end of the pipe is

[1] A more complete description of the way a carburetor is made and works will be found in "Keeping Up With Your Motor Car," by the present author and published by D. Appleton and Co., New York.

bent up and is fitted with a nozzle. In this case the gasoline will squirt from the nozzle in a stream like a jet of water from a hose-pipe.

Now for fuel purposes the gasoline must be mixed with a certain amount of air and made into a spray, and if it is heated to vaporize it a better fuel mixture will be made. To form a spray the nozzle of the

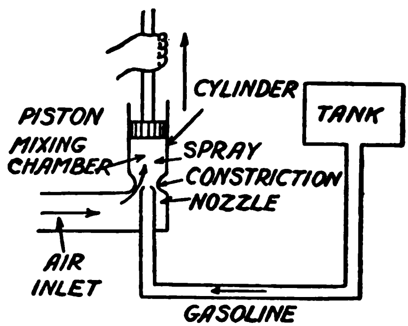

Fig. 43.—How a Carburetor Works

gasoline supply pipe must be enclosed in a larger tube, which is contracted at a point just below the jet formed by the gasoline, all of which is shown in Fig. 43.

If air is blown through the inlet end of the contracted tube or if it is enclosed through the outlet end—which in a real carburetor is connected to the cylinder of the engine—it (the air) will be mixed with the gasoline and because of the high pressure of air set up by the contracted part of the tube the gasoline will be

broken up into fine particles, and mixed with the air when a spray is formed.

A real carburetor works in precisely the same manner, but it is somewhat more complicated because there

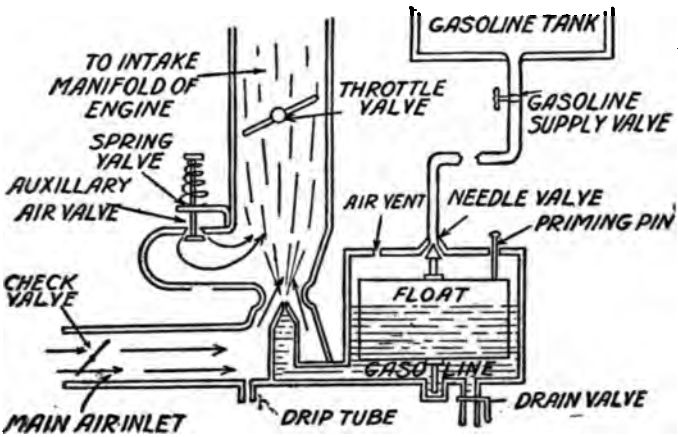

FIG. 44.—CROSS SECTION OF A SIMPLE CARBURETOR

are a few other parts to it to regulate the supply of gasoline and the quantity of air mixed with it.

The supply of gasoline flowing from the tank into the carburetor is regulated by means of a *float valve,* as shown in Fig. 44. The whole arrangement consists of a *float chamber* connected to and in between the gasoline tank and the nozzle.

A hollow metal *float* is placed in the *float chamber,* and this is fitted into the *mixing chamber,* which when the gasoline in the float chamber has reached a cer-

tain high level the float will rise and close the valve, and as the engine uses up the gasoline in the float chamber the float will fall, the valve opens and more gasoline will flow into the float chamber again.

There is another valve called the *auxiliary air valve,* and this is fitted into the mixing chamber, into which the spray nozzle opens; it is normally held shut by a spring, but can be opened by the air pressure acting outside against it.

The purpose of this extra valve is to allow more air to get into the mixing chamber than the ordinary air inlet can supply, and when this is needed the outside air pressure forces the valve open against the spring.

When a *rich mixture,* that is, one in which there is very little air and a large amount of gasoline, is required the valve is kept closed by the spring, but when a *lean mixture,* that is, one in which very little gasoline and a large amount of air is required by the engine, the air automatically forces the valve open and supplies it.

In some types of carburetors used in *aëronautical* engines the needle valve is set under the float and as the float rises and falls it lifts and lowers a weighted lever which is attached to the needle valve. In other kinds the nozzle is fixed in the center of the float chamber and passes through a hole in the float, the needle valve is placed in a separate chamber outside of but

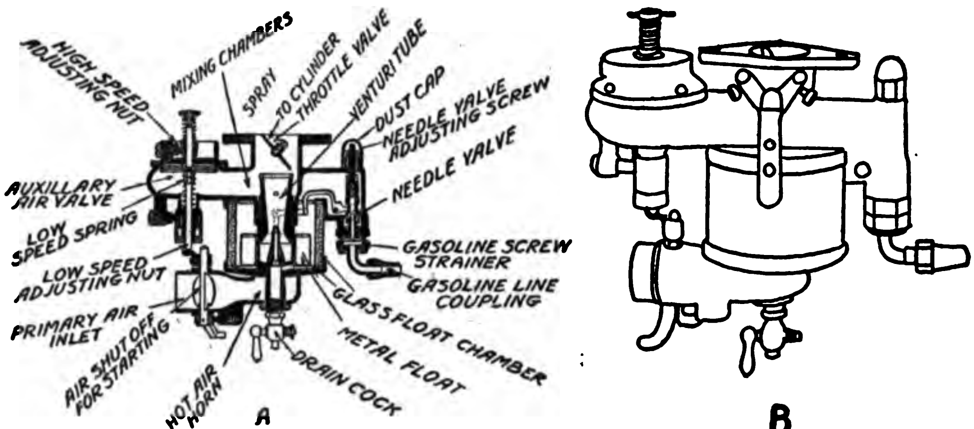

FIG. 45.—A. CROSS SECTION OF A STROMBERG CARBURETOR
B. A STROMBERG CARBURETOR COMPLETE

connected with the float chamber and the needle valve is operated by the float through a series of levers.

A cross-section of a Stromberg carburetor is shown at A in Fig. 45 and ready to use at B.

Different from an automobile engine the speed of an aëroplane engine once that it is started is never changed; this scheme not only does away with *throttle* and *spark levers* and with *clutches* and *transmission gears,* but it acts as a factor of safety.

Suppose for instance that you had a motor which you could throttle down and you were flying at a low speed, then should you suddenly strike a hole in the air before you could accelerate your motor and get the lifting power necessary to pull you out of it, you would have lost so much headway you could not possibly right your machine again.

With an engine, however, which is constantly running at its maximum speed, and hence is developing its greatest power, such an accident is practically impossible.

How the Magneto Makes a Spark.—To *ignite,* that is, to set fire to the gas when it is compressed in the cylinder, an electric spark, called a *jump-spark,* is used.

The *spark,* as it is called for short, can be made with either (1) a *battery* and an *induction coil,* or (2) a *high tension magneto.* As a battery and an induction coil do not give as good results as a magneto the latter is used

altogether on aëroplane engines, and hence the magneto only will be described.

The simple magneto which generates a low tension current of electricity is made up of a powerful permanent steel U magnet, as shown at A in Fig. 46. Between the ends, or *poles,* of the magnet an *armature* is mounted. The armature is made of a round soft iron

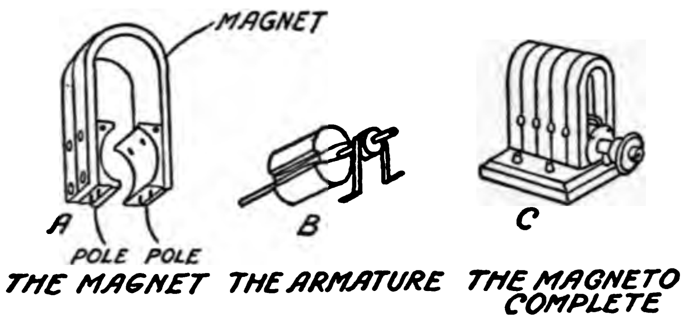

FIG. 46.—THE LOW TENSION MAGNETO. A. THE MAGNET. B. THE ARMATURE. C. THE COMPLETE MAGNETO

bar with slots cut lengthwise in it, as shown at B, and these are wound full of very fine wire.

A steel shaft runs through the center of the armature, and on one end of the shaft there is a ring of hard rubber, or other insulating material; to the outside of this insulating ring two brass rings, called *collector rings,* or *sliprings,* are fastened. To each one of the rings an end of a fine coil of wire is soldered and a copper strip, called a *brush,* presses on each slipring and these take off the currents. The armature is

mounted in bearings between the poles of the magnet so that it will turn freely, as shown at C.

The magneto works like this: as each coil of wire moves past each pole it cuts through the magnetic lines of force that flow from one pole of the magnet to the other, and this sets up alternating currents of low pressure, or *tension,* which means the same thing.

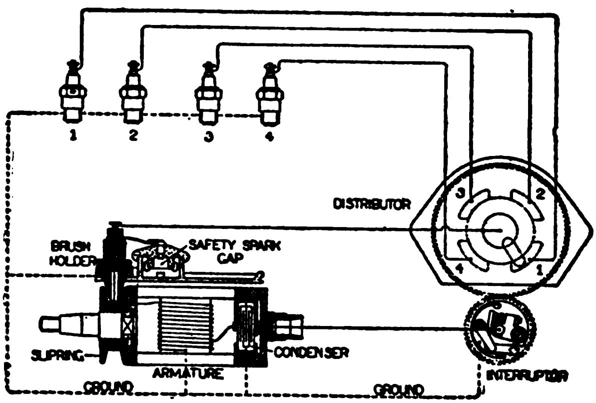

FIG. 47.—A BOSCH HIGH TENSION MAGNETO

These currents are then made to flow into the primary coil of an induction coil when they are stepped up into high tension currents in a secondary coil; they are then conducted by heavy, rubber insulated copper wires to a *distributor,* which will be described presently, and the *spark-plug* of the engine, as shown in the wiring diagram, Fig. 47. The spark-plug is simply an insulating tube in which a pair of wires are fixed and

whose lower ends are separated by about $\frac{1}{16}$ inch and so forms a *spark-gap.*

When the armature of the magneto is rotated by being belted to or connected with the shaft of the motor the high tension currents jump across the gap of the spark-plug every time the distributor *makes* the circuit, that is, closes it, and in this way the gas in the cylinder is fired at the right instant.

The Bosch Ignition System.—The Bosch magneto is made a little differently from the ordinary magneto, as described above.

The armature generates the low and the high tension currents itself; in order to do this, it is wound with two sizes of wire, one thick and one fine; the thick wire winding forms the *primary coil,* or *low tension circuit,* and the fine wire winding forms the *secondary coil,* or *high tension* circuit.

When the armature rotates between the poles of the magnet alternating currents are set up in the primary coil, and as this is connected to an *interruptor* the current is made and broken. When the interruptor breaks the primary circuit a current of high *voltage,* or high tension, is *induced,* that is set up in the secondary circuit of the armature.

This latter current charges the condenser in the end of the armature, and when this discharges it is taken off by a single brush, whence it goes to the spark-plug through the *distributor,* and the circuit is completed

by a *ground,* shown by the dotted line, which is the metal work of the engine, and this serves as a return wire.

In order that each spark-plug may receive its sparking current at the proper instant a timing device called a *distributor* is used. The high tension current is taken off by the brush of the slipring and the bar under the magnets leads the current to the metal contact in the center of the distributor plate, as shown in Fig. 46.

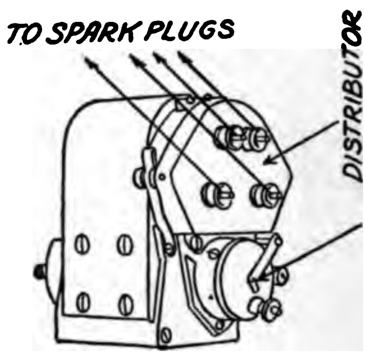

Fig. 48.—A Wiring Diagram of a Magneto, Timer and Spark Plug

From this plate the current flows to the ***distributor brush,*** which is fastened to and consequently turns with the distributor gear. Metal segments are embedded in the distributor plate, and as the distributor brush rotates it makes contact successively with the segments in the distributor plate. The segments are connected by high

tension cables with the spark-plugs in the various cylinders.

In the cylinders the high tension current produces a spark which ignites the gas mixture, and the current then returns through the engine to the armature, thus completing the circuit. The magneto with its interruptor and distributor is shown in Fig. 48.

The Purpose of Multi-Cylinders.—Since there is only one explosion to every four strokes of the piston it is obvious that if the engine has two cylinders the pistons can be connected to the *crank shaft* in such a way that while one of them is being forced down by an explosion the other piston will be moving up and pushing out the gases, and this will give two impulses to every four strokes.

Where four cylinders are used four explosions will take place to every four strokes, and so on. The diagram, Fig. 49, shows how the pistons of a four-cylinder motor are connected to the crank shaft to get this effective result.

Adding to the number of cylinders not only gives the engine more power and makes it run smoother, but it is more trustworthy, since if one cylinder should miss fire the others give it enough power to keep it going.

Air and Water Cooled Engine.—To keep the cylinders from getting too hot two schemes are used. One is to fasten a lot of thin rings around the cylinder and parallel with each other; as the cylinder heats up

the rings *radiate*, that is, give off heat in the air, but to cool a cylinder enough a stream of air must strike

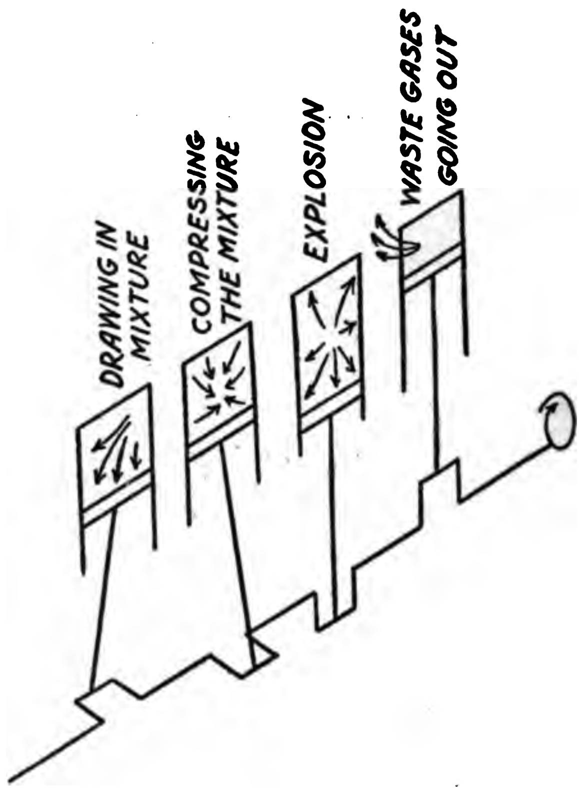

FIG. 49.—DIAGRAM OF A MULTI-CYLINDER ENGINE

it. Rotary engines are air-cooled, for they revolve at such high speeds there is no need of water cooling.

In a water-cooled engine each cylinder is *jacketed*,

that is, each one has another cylinder outside of it, as shown in Fig. 50, and cold water is forced between the cylinder and the jacket by a pump. The water is kept cool by a *rotary pump* forcing it through a lot of small tubes exposed to the air, and such an arrangement is called a *radiator.*

The Position of the Engine.—The engine is usu-

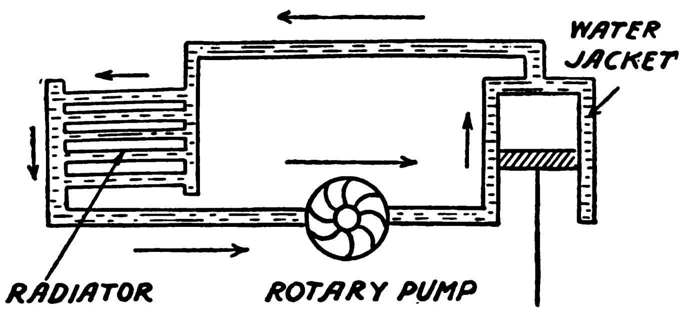

FIG. 50.—A WATER-COOLED CYLINDER

ally set in the front of the body or on the lower main plane near the middle.

Apart from what might happen if the machine should fall the position of the engine matters but very little as long as the center of gravity and the resultant center of pressure are at the same point in the machine. In some tractors the engine with its radiator is set in front with seats behind exactly as in an automobile, and this is the right place for them.

Building-in the Engine.—To *build-in* the engine

means to fix it in position; when the body, or frame, of the machine is made of wood it is easy to bolt the engine down to a wood base, which is in turn bolted to the frame, or the engine can be bolted to I or T steel beams, and these can be bolted to the framework.

The Power of Engines.—The horse power needed for an aëroplane depends on the area of the wing surface and on the amount of weight to be carried.

The smallest engine ever used on an aëroplane had two cylinders and developed 18 horse power. The Wrights used a 25-horse-power engine on their first machine and the power has been going up ever since. The *gyro-duplex* engine is built in 90- and 110-horse-power sizes, while other aëroplane engines are rated as high as 325 horse power.

Some Recent American Engines.—*The Hispano-Luiza-Engine.*—This engine, which is built in this country by the Wright-Martin Aircraft Corporation, represents the highest development of aëroplane engine practice abroad.

The model A is a water-cooled, 4-angle V-type of engine with 8 cylinders, and it develops 150 horse power at 1,450 revolutions per minute. The weight of the engine with its carburetor, two magnetos, starting magneto and crank, but without water or oil or exhaust pipes, is 445 pounds. The average fuel consumption is 5 pounds of gasoline per horse-power hour.

The water jackets and valve ports are cast aluminum,

and each cylinder is made of a heat-tested forging threaded into the bored holes of the aluminum castings. Four cylinders are contained in each block which forms this built-up construction.

The pistons are of cast aluminum and ribbed, and the connecting rods are tubular and of the forked type.

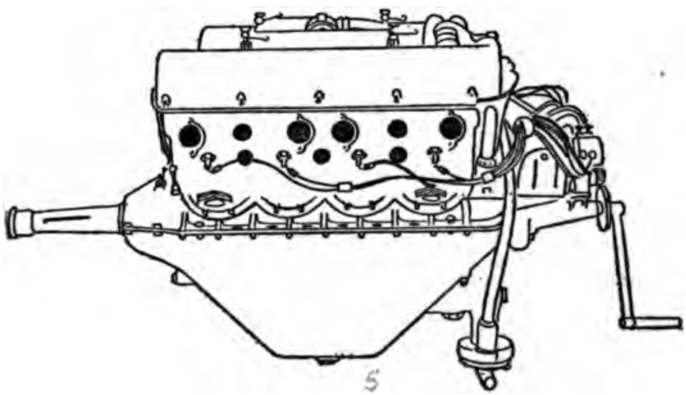

FIG. 51.—THE NEW HISPANO-LUIZA (WRIGHT & MARTIN) ENGINE

The valves are of large diameter with hollow stems working in cast-iron bushings.

A positive pressure oiling system is used, and the ignition system consists of two eight-cylinder magnetos firing two spark-plugs per cylinder. The carburetor is mounted between the two cylinder blocks. The engine can be fitted with a geared hand crank for starting if desired. It is shown in Fig. 51.

The Curtiss Model V2 Engine.—The Curtiss en-

gine, shown in Fig. 52, has eight cylinders, four set on a side forming a V unit. It weighs 565 pounds, runs at a speed of 1,300 revolutions per minute and develops 160 horse power.

The cylinders of this engine are made of steel; an aluminum alloy is used for the pistons and the exhaust springs are of the *rat-trap* type. The engine is fitted

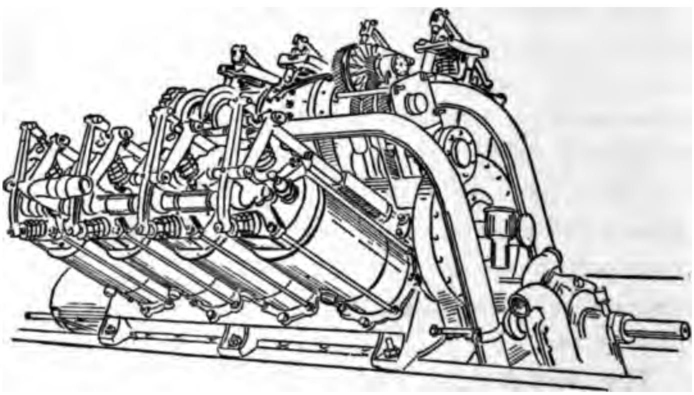

FIG. 52.—A CURTISS MODEL V2 ENGINE

with two magnetos and two carburetors and it is water-cooled.

The Sturtevant 5A Eight Engine.—This new engine is built largely of aluminum, even the cylinders being of that metal; it is of the eight cylinder V type. It weighs 580 pounds, runs at a speed of 2,000 revolutions per minute and develops 140 horse power. It is fitted with a *Zenith* duplex carburetor.

The Thomas Model Eight Engine.—This engine has cast-iron cylinders and aluminum pistons. It weighs 525 pounds, runs at a speed of 2,000 revolutions per minute and develops 150 horse power. The Thomas Company also has a new model on the stocks, in which the cylinders are of cast aluminum, and this will be ready for delivery shortly.

The Hall-Scott A5a Six Engine.—It is the contention of the makers of this engine that the four- and six-cylinder engines are better suited to the power requirements of airplanes than the eight- and twelve-cylinder engines of the same horse power in that they can be built more sturdily. The weight of the A5a engine is 525 pounds, it runs at a speed of 1,250 revolutions per minute and develops 140 horse power. Two magnetos are used for ignition, and each cylinder is fired by two sets of spark-plugs.

The Aëromarine Twelve Engine.—This twelve-cylinder engine is of an entirely new design. Its construction is such that when an aëroplane equipped with it is flying upside down or looping-the-loop it will not overheat. Its weight is 750 pounds and it delivers 150 horse power.

The Gyro Engine.—This type of engine is like the *Gnôme* and *La Rhône* engines built abroad in that its cylinders revolve. Neither the cylinders nor the pistons have any to and fro motion, but each of them turns round a separate center. This type of engine is air-

cooled and is the lightest yet made for the horse power developed. In fact all altitude and speed records have been made with aëroplanes powered with revolving engines.

The way it works will be clear if you will look at

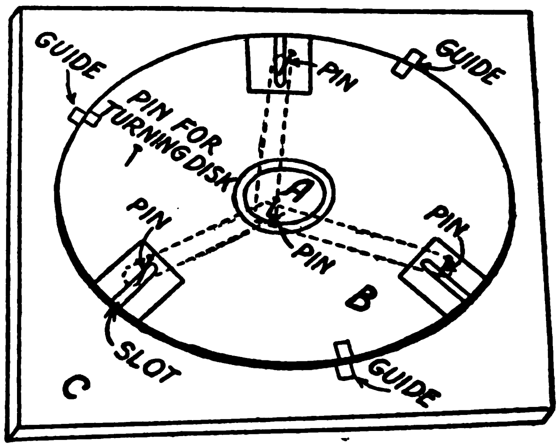

FIG. 53.—DIAGRAM SHOWING HOW A GYRO ENGINE WORKS

Fig. 53; the ends of all of the piston rods are fixed to a hub like the spokes of a wheel and the other ends of the rods are fastened to the pistons, the hub is fastened to an axle, or journal, but neither of these parts move. It is shown complete in Fig. 54.

The cylinders in which the pistons move form a big, spoked wheel, and this turns round on the hub with the curious result that instead of the pistons turning a shaft the explosions force the cylinders round, and

this action turns the shaft. Fig. 55 shows how the engine is built in a tractor biplane, and Fig. 56 is a photograph of a gyro-engine mounted on a Wright biplane.

The gyro-engine is built of vanadium and nickel steel;

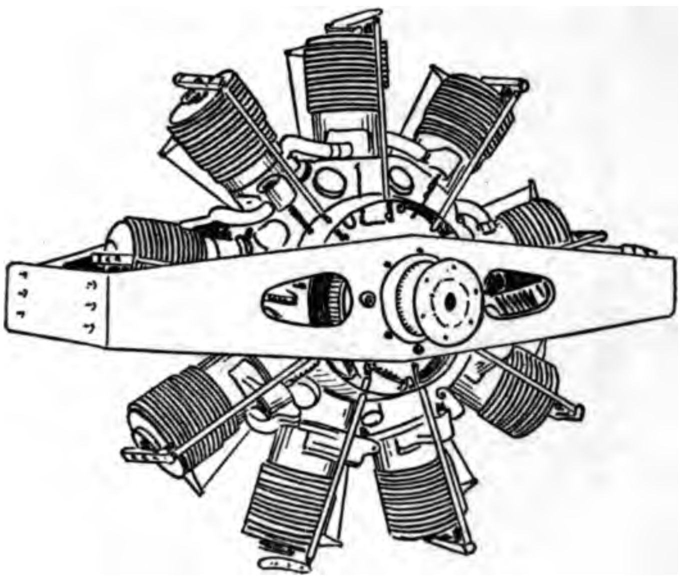

FIG. 54.—THE GYRO ENGINE MOUNTED IN A STANDARD FRAME

it has nine cylinders, weighs 270 pounds and develops 110 horse power.

Self-Starting Engines.—Nearly every high-grade aëroplane engine now turned out is fitted with a self-starting motor. The latter is operated by compressed

air and this cranks the engine in the same manner that an electric motor cranks an automobile engine.

The Use of Mufflers.—Until recently mufflers were not used on aëroplane engines, for while the noise of the

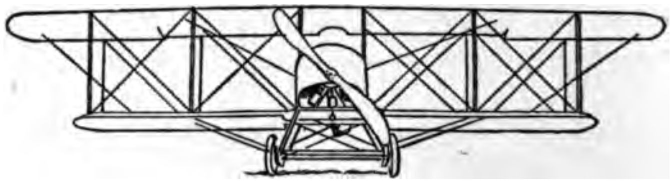

FIG. 55.—A GYRO ENGINE MOUNTED ON A TRACTOR BIPLANE

exhaust racked the nerves of the pilots they were able to gauge the working of the engine by it.

In these strenuous war times, however, mufflers are a necessity not only because they prevent the enemy

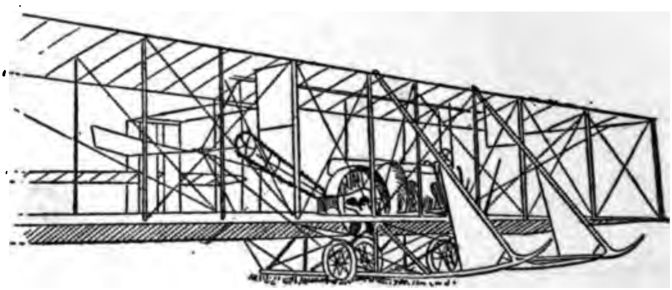

FIG. 56.—A GYRO ENGINE MOUNTED IN A WRIGHT BIPLANE

from detecting the approach of an invading aëroplane, but because the noise of the exhaust must be suppressed so that the pilot and the gunner on scout who is with

him can converse and also that wireless messages can be received.

How Engines Drive the Propellers.—There are three ways of connecting the engine to the propeller, or

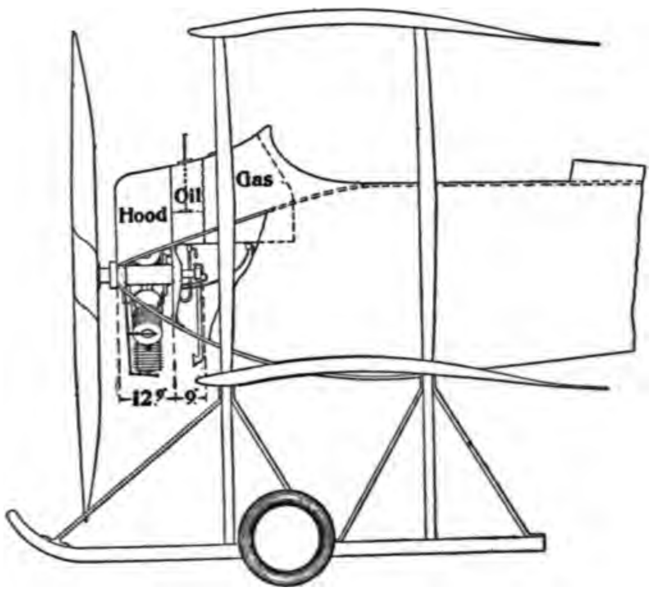

FIG. 57.—A DIRECT DRIVEN PROPELLER

transmission as it is called; and these are (1) direct; (2) by gears and (3) by chains.

The first way is called a *direct drive* because the propeller is fastened directly to the end of the shaft of the engine, as shown in Fig. 57; the second is by gears, or cog wheels, when the engine is connected to

one gear and the propeller to another gear, and as these gears mesh with each other the engine drives the propeller.

The third way is to have a pair of sprocket wheels fixed to the shaft of the engine and one to each of the

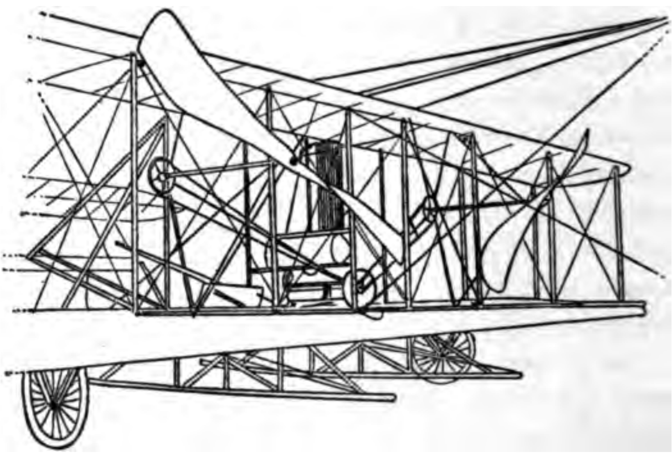

FIG. 58.—A CHAIN DRIVEN PROPELLER

shafts of the propeller, and to connect them with chains as on a bicycle. This is called a *chain drive,* and is clearly shown in Fig. 58.

A Final Word About Propellers.—Many kinds of propellers have been designed to the end that a perfect one might be made, but there is a lot to be found out about them yet. The Wright propellers are the most efficient that are made at the present time.

Propellers are made of wood and of metal; most of

them have only two blades, while some have three and even four blades. They are made in all sizes, of all pitches and are driven at all speeds—within certain limits, of course.

The smallest propeller ever used was only 6 feet in diameter, had a pitch of 4 feet and was driven at 670 revolutions per minute. The largest propeller to date had a diameter of 10½ feet, a 10½-foot pitch and was driven at 690 revolutions per minute. From what has been said in this and the foregoing chapters you will see that an aëroplane can be given almost any shape and that it will fly if it has speed enough, but to design a safe aëroplane it takes the skill akin to that of a Wright or Curtiss. There are many kinds of materials to choose from, but the choice must be a wise one, and every part that enters into the construction of the machine must be rigidly tested. The schemes for the controls are numerous, but the test is the simplest and this is the Dep, which has been previously described in Chapter IV. Finally there is a wide range of power plants built for aëroplane work, but you want one that is built by the most experienced aëronautical engineers if you are to be on the quick side of the earth's surface.

CHAPTER VI

HOW TO BECOME A PILOT

And now the time draws near when you will learn how to fly. What I intend to try to do is to tell you how to learn to fly and obtain your pilot's license in the shortest possible time and with the least possible danger.

It is said that there are a few people who could never learn to ride a bicycle, and it is certain there are some people who couldn't learn to walk a tight rope or be a steeple-jack. So, too, there are a few fellows who haven't the mental make-up which would permit them to fly with safety. And now let's find out just what qualities a man must have to make him a good flier.

Personal Adaptation.—There are five things you ought to have if you arc to become an expert aviator, and these are: (1) youth, (2) natural aptitude, (3) good sense, (4) knowledge, and (5) confidence. The value which I have arbitrarily put on each of the above factors is shown in the diagram, Fig. 59, and, as you will see, youth is of the least importance and confidence is the greatest.

Youth.—To begin with, you should be young, for

this means that you will be apt to learn the new tricks of the air easily, but on the other hand you should not be too young. Choosing one's age, however, is very like choosing one's parents—you can't always do it.

While there are a few *licensed pilots* who are only 18 or 19 years of age, you should not learn to fly until you are 20 at least. Nor should you learn to fly after

YOUTH.................5%
NATURAL APTITUDE.......15%
GOOD SENSE............15%
KNOWLEDGE.............25%
CONFIDENCE............40%
EQUALS
SKILL.................100%

FIG. 59.—DIAGRAM SHOWING QUALIFICATIONS NEEDED BY A PILOT

you are 35, although this may be putting the age limit a little too low, for many men have learned who are past the 50 mark.

I'll qualify what I have said above by adding that the younger men usually learn to fly much easier and quicker than those who are middle age.

Natural Aptitude.—To do the right thing at the right instant without having to think about it is what is meant by *natural aptitude* and human beings are born with this power as well as the lower animals.

Natural aptitude in flying means that you have the ability to keep your aëroplane right side up and level under all conditions by pulling a lever, pushing a foot-bar or turning a wheel at the instant needed and without having to think about it.

While birds and monkeys have this natural aptitude very strong in them, man has it only to a slight extent because, unlike his feathered competitors and primordial ancestors who lived in the air and the trees, he has had no use for it. But it still lingers in every person a little and it is much more marked in some people than in others.

Natural aptitude can be wonderfully increased by practice, and almost anyone can develop it for whatever purpose he wishes to put it to by doing the thing over and over again. Walking on stilts, riding a bicycle, or steadying an aëroplane can all be learned by using such natural aptitude as you have and then practicing until you have learned the trick. And once you are able to do it you can handle any of these devices with yourself on it without the least further thought or effort.

Good Sense.—However well you may have developed your natural aptitude it is not enough in itself to make you a good aviator; you must help it over the more difficult places with good, sound sense—that is, if you expect to fly another day.

By *good sense* I mean that you must not only know

what to do, but when to do it, and do it under all sorts of conditions which you will meet with before you start, when you start, when you are in flight, and when you land.

An aviator having good sense will not attempt to fly when the wind is so high or so gusty that he knows it is not safe to go up. Of all the accidents which aviators have met with, between 80 and 85 per cent were caused by high winds. It is the fellows who fly in gusty winds, make steep dips, turn sharp curves, loop-the-loop, and do other spectacular but useless stunts who come to grief.

But using good sense does not begin and end when you are flying. You need it when you are making a getaway if there are trees or other obstacles in the way, in the air when some little thing goes wrong, and in landing when you will have to pick out the right place and gauge distances.

With all their other flying qualities put together, plus good machines but minus good sense, Wright and Curtiss and other pilots like them could not have kept up their flights these many years and still stay in the class of those who fly with engine-driven wings. Be like them and use good sense, and flying will be as safe as driving a motor boat or automobile.

Knowledge.—If you have studied up on the subject of mechanical flight you will be greatly helped not only when you take the controls of a machine in your hands

for the first time, but ever afterward, though you may not realize it.

To know how your machine is built and balanced, how the engine works and what it can and might do, about the air when it is at rest and in motion and what its effect on your aëroplane is apt to be under varying conditions, are products of learning that are of the greatest importance but ones that are too often overlooked by beginners and sometimes by the older fliers.

Confidence.—A person whose knees knock together whenever he looks out of a sixth-story window or who is afraid to climb to the top of an 800-foot mountain has no business with an aëroplane.

An aëronaut who can hang by his toes from the trapeze bar of a balloon while it is going up at the rate of 400 feet a minute, cut his parachute loose when he is up a mile or so and drop 1,000 feet before it opens has an over-supply of aëronautical nerve, and looping-the-loop would be too tame for him.

But fortunately there is a happy medium between these extremes of timidity and foolhardiness, and nearly everyone is so mentally balanced that he has all the necessary courage to fly and yet no desire to risk his life uselessly in so doing.

Flying, though, is like everything else that seems risky to an onlooker—it soon gets to be common and everybody will get used to it just as they get used to motoring. Whatever may be your thoughts and feel-

ings before you make a flight for the first time, the moment you realize that you are really flying you will give a sigh of *safety-first relief,* for you know that at last you are above the world and all of its dangers.

And as you get off the ground and speed through space you feel the thrill of a new sensation surging through your blood and you wish you could keep right on flying. From this time on, wherever you are, you will hear the call of the air and it will sound good to you.

To make a good pilot, then, you must have a large supply of confidence both in yourself and in your machine. If this is tempered with good sense and you have a natural aptitude for flying you will be fit to join the great flock of birdmen and to share the freedom of the air with them.

Skill.—While you may have a fair share of natural aptitude, may be gifted with a large measure of good sense, may be possessed of much knowledge, and have all the confidence an aviator needs to be a really skillful pilot, you must be able to *correlate* them; that is, make them work together just as though they were a lot of cogwheels meshing with each other.

And, what is more, not only must these factors work smoothly together, but they must do so just as though it were second nature with you. Yet with all of these things you will not be counted skillful unless you can

bring *quick action* to bear when it is needed. An astronomer may be skillful and work slowly, but an aviator, to be skillful, must be able to work fast.

Measure yourself by the standards I have set and you can readily figure out whether or not you will make a successful pilot.

How to Learn to Fly.—There are two ways open for you to learn to fly, and these are: (1) by teaching yourself; and (2) by joining an aviation school.

Training Camps.—The easiest and safest way is the last-named way and as the *tuition,* that is, the amount you pay for taking a course at a training camp, is usually deducted from the cost of a machine if you buy one, this is the cheapest and best way in the end.

Quite a number of companies maintain schools and flying fields and have practice machines that are fitted with *dual controls* so that both you and the pilot who instructs you have a wheel at the same time and you learn to fly the machine with a minimum of danger.

After you have learned the things that are set down in this book you will be well prepared to take a course at the training camp. Under these conditions, if you are an apt pupil, you will only need to fly half an hour a day for a week until you can get your pilot's license.

Routine Method.—Whether you are learning to fly by yourself or at a camp, the first thing you should do is to go over the machine and understand every detail of

its construction, and you should know the engine, too.

Next, you take your seat and have the men start the engine, which they do by turning the propellers round; then the men hold the machine to keep it from getting away from you until you are ready and say, *"Let her go."*

First you run the machine along the ground like a wind-wagon, and you need a big level field to do it on, for you steer it with the rudder. When you get this control down fine run the machine on the ground and balance it on one wheel; this will quickly teach you how to warp the wings, shift the ailerons, or control the elevating planes.

Starting Up.—As soon as you are able to do the above things you will have no trouble in flying; indeed your greatest difficulty will be not to fly.

In starting to make an actual flight turn your machine so that it *faces* the wind. Climb into your seat and have your helpers hold on until you are ready to start. Give your engine plenty of gas, and when your propellers are turning at their top speed you signal to let her go.

As you run along the ground your aëroplane gathers speed until finally the tail lifts from the ground a little, as shown in Fig. 60. Then you tilt the elevating plane and the nose of your machine goes up and you leave the ground so gently you would not know it except that the riding is smoother. Then up and away your modern

pterodactyl [1] soars as high and as far as your heart desires—or, at least, as you and it can stand.

Making a Landing.—To fly is easy, but it's the landing that sometimes hurts. At first you should only make short, straightaway, flights and keep within a few feet of the ground.

When you are making a landing always keep your engine running and see to it that your machine faces the wind. If you stop your engine just before you touch

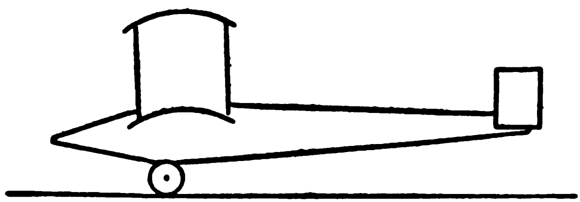

FIG. 60.—WHEN AN AËROPLANE STARTS
When starting, the tail lifts from the ground first

the earth your machine may fall, and if you land with the wind at your back it may tip over on its nose.

When Flying.—When you have learned to land, which is the hardest part of the whole art of flying, and have grown skillful in handling your aëroplane on short, straightaway flights, you are ready to try your head and hand at turning, and you begin by making large curves.

Just as a train must tilt inward, on rounding a curve,

[1] An extinct flying reptile and the largest living thing that ever flew.

to keep it from jumping the track, so an aëroplane must be tilted inward, or *banked,* as it is called, when you turn it, or it will lose its sidewise balance and take a tumble.

When the machine is banked the wings offer a smaller

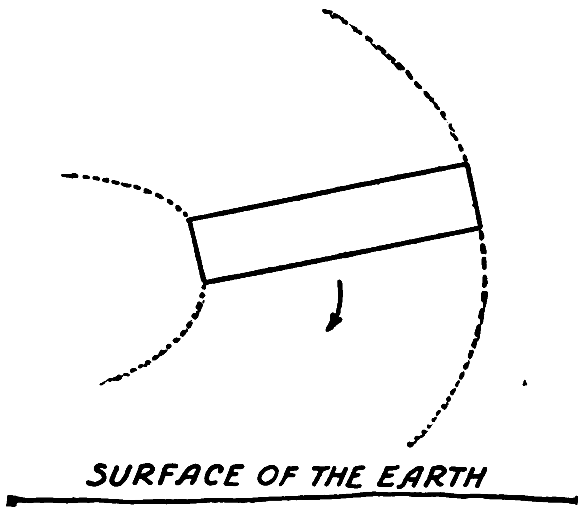

Fig. 61.—Banking the Machine
In turning, the machine must be banked

lifting surface than when they are level, that is, horizontal with the earth's surface; then the inside wing, since it moves slower than the outside wing, begins to sink and if you are not careful it will go farther down than you intended and keep right on slipping, all of which is shown in Fig. 61.

To right it you warp the outside wing or raise the inside aileron, which gives the inside wing a larger surface than the outside wing, and this brings the machine back to its proper position again. It is this control of the wings, or ailerons, which will give you a good chance

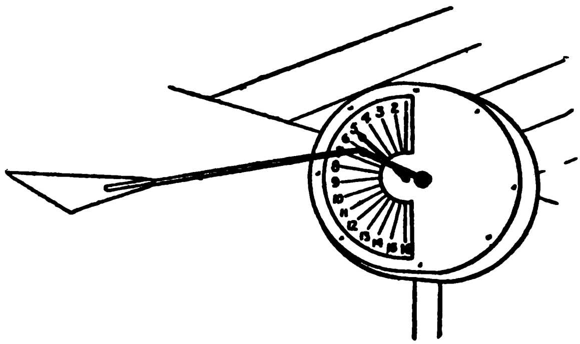

Fig. 62.—The Wright Angle of Incidence Indicator

to show your natural aptitude and a few other personal qualities.

All machines should be fitted with an ***incidence indicator,*** one of which is shown in Fig. 62. This indicator enables a flyer—be he pupil or pilot—to know the *angle* of his machine with relation to the surface of the earth, and hence he can always be sure of remaining in a safe flying position.

The Glide, or Volplane.—When you have become thoroughly proficient in making figure eights you have one more thing to learn before you can qualify for a

pilot's license (see Chapter IX) and that is to glide, or volplane, to the earth with your engine shut off.

The best way to do this is to head the machine toward the earth at its *natural gliding angle* before you stop the engine. When the machine gathers speed steer it so

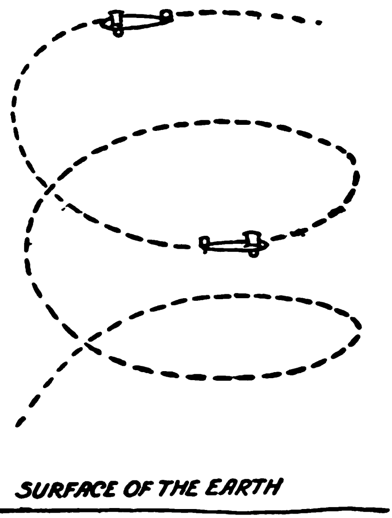

FIG. 63.—MAKING A SPIRAL VOLPLANE

that its path will be a great spiral, as shown in Fig. 63. If you can start your motor you can, of course, straighten up your aëroplane and steer it as you will again; but if it is *dead* the only thing you can do is to make a landing.

When your machine is within 100 feet of the ground tilt up your elevating plane and this will make it nose

up a bit and glide off at a *tangent,* as shown in Fig. 64, and as you are more nearly parallel with the ground you can strike it very gently. You can't make this kind of landing, though, if the machine isn't going fast enough.

When you are flying it is a good scheme always to

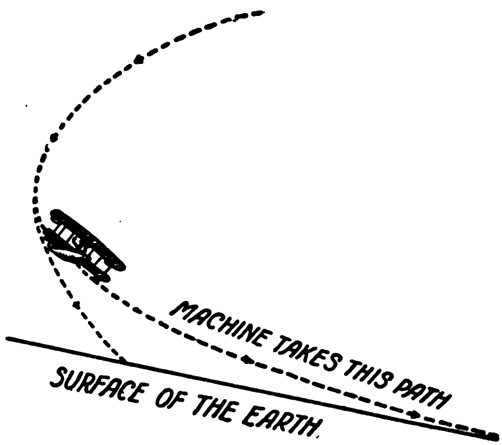

FIG. 64.—MAKING A TANGENT LANDING

keep the tail of your machine a trifle higher than its nose, so that should your engine *go dead* when you are not expecting it your aëroplane will already be pointed down ready for a glide; otherwise it might lose headway and fall to the earth tail first.

The reason the volplane is added to the other tests required to get a pilot's license is so that you will know what to do when your engine stops suddenly. The main

thing is to keep your nerve and bring your skill to bear and you will make the glide to earth safely.

High Flying.—It is much safer to fly high than it is to fly low, for while the wind usually blows harder, the higher you get the steadier it is. Another thing: by flying high you have more time and a longer distance in which to bring your machine to the gliding angle should your supply of gasoline give out and your engine stop, and for the same reason it is easier to choose a good place to land, especially if you are flying over a city.

Buying a Machine.—When you have learned to fly you will have some very clear-cut ideas on the kind of a machine you want. Should you intend to get a machine and then learn to fly don't fool yourself into the belief that you can design and build one yourself that will be better or cheaper than those sold in the open market.

No, you can't do it even if you are a mechanical engineer with an M.E. tacked after your name and you have skilled workmen at your beck and call. What you ought to do is to learn to fly first and then buy a machine from some good reliable maker, for in this way you will have money in pocket and keep your soul and body together a little longer than by doing everything yourself.

By flying first and buying a machine afterward you will have a much better idea of what you want and

what you can get than if you buy first and then fly. However, it is well to remember that a biplane is safer than a monoplane in virtue of the additional pair of wings and the fact that they are joined together by stanchions.

If all of your flying is to be done over land or your landing place is the ground get an aëroplane mounted on a *chassis* with wheels. If you live on a lake or a river and you can use these for starting and alighting, a flying boat is the machine to get.

Then you have to choose between a machine that is a tractor and one that is a pusher. For purposes of learning an ordinary pusher biplane is better than a tractor, as the latter is built more especially for scouting and military work.

The Speed of an Aëroplane.—As the speed of all things that move on the surface of the earth is measured by the time taken for them to travel a certain distance, when men began to fly the speed of aëroplanes was figured out in the same way.

Now the speed of an aëroplane depends not only on its own power but on the strength and direction of the wind in which it is moving, and not on the ground over which it is flying. Say, for instance, that the wind is blowing 25 miles an hour and the aviator in his machine is moving against it at 25 miles per hour, then to an observer on the ground it would seem that the machine is standing still.

But if the wind is blowing 25 miles an hour and the aviator is moving with it at a speed of 25 miles an hour, it would seem to the observer on the ground that the machine is making 50 miles an hour. In calculating the speed of an aëroplane the strength and the direction of the wind must always be taken into account.

Finding Your Way Through the Air.—In flying it is often very hard to know just where you are, though you may know the lay of the land well enough when you are traveling on it.

A bird's-eye view of the country in flying over it is a new and strange sight to the eyes of mankind. The best way to find your course through the air is by the use of maps which show the chief landmarks and the best places to make a landing.

An *air compass* is indispensable for long-distance flying. In this type of compass the bowl is supported in the binnacle on three rubber-covered trunnions which, together with a quantity of horse-hair packing in the bottom of the binnacle bowl, absorbs all vibration; this gives a very steady *card.*

Useful additions to the compass are a magnifying prism and having the card graduations painted with luminous paint. The prism enables the compass to be located on a level with the eye, which gives perfect clearance for operating the controls; and the luminous card obviates the uncertainty of electrical illumination.

It is necessary, however, to equip the compass with

an electric lamp, which will give all the light needed on one dry cell. This light is needed only at twilight, when it is not dark enough for the luminous paint to show the card clearly. The Sperry Gyroscope Company of Brooklyn, New York, are the makers of these compasses. (See Appendix.)

Other Things to Know.—There are, of course, a few other things to be learned about flying, but they will come to you without effort when you have made a few flights by yourself. When you can fly well enough to get your pilot's license you can consider that you are in very truth a *birdman.*

CHAPTER VII

WHERE TO LEARN TO FLY

Alan R. Hauley, Secretary of the Aëro Club of America, says that there are 19,000,000 men of military age in this country, and there is evidence that a large percentage of these men will learn to fly as soon as they get the opportunity.

He further states that there are at the present time only about 100 trained military aviators in the United States and that there are plans in the air to train about 400 more men in the near future. There is a general appreciation of the fact that if the United States had 5,000 trained aviators it would be in the position of the porcupine who goes about its daily pursuits and harms no one, but is prepared to defend itself on a moment's notice.

These 5,000 aviators can be obtained and they can be employed every day for useful purposes, such as carrying mail, in the Coast Guard service, and in other peaceful pursuits. The Post Office is ready to establish aërial mail-carrying in 200 localities, and this will easily take 1,000 aëroplanes and pilots.

From the above statements of Mr. Hauley it is ob-

vious that this country needs trained pilots. There is an opening for any civilian flyer to enter the reserves of the Army and Navy. Moreover, there will be an increasing yearly demand for aviators for the Army and Navy, postal service, pleasure-craft pilots for touring and ferry service, high-speed express lines, and innumerable new and as yet unthought of applications of air-craft.

Learning to Fly.—Learning to fly at a flying school is as simple as learning to drive an automobile. All instruction machines are fitted with dual controls; you take the same seat that you will always occupy, and from the starting of the engine you follow every movement of the instructor in getting under way, rising in the air, maneuvering, and finally landing, until these operations become second nature.

Gradually the pilot gives the actual control of the machine to you while you are in the air and you soon get so that you are able to handle it under every condition of flight. Instruction and practice are then continued until the student can leave and land with perfect assurance.

Aëroplanes Used.—In the Wright school you are first taught on an old style Wright *Model B,* which is acknowledged to be the world's safest and most efficient aëroplane, and from this you go to the single and double tractors, in speed and weight carrying and sporting and military types of machines.

Time Required.—The courses include as a minimum a total of five or six hours' flying on your part. The lessons are given in series of from five to fifteen minutes' duration and in regular rotation in as many daily units as weather conditions will permit.

Sufficient additional instruction is given to pupils to insure complete competency in flight and the granting of a certificate. Should you for any reason not show aptitude for flying most schools will return your tuition fee *pro rata.*

Construction and Care.—As a pupil you are given full access to details of construction and repair; further, you are given careful training in the examination and care of machines, assembling, taking down, packing, engine overhauling, etc., and you are expected to assist in all alterations, setting up, repairing, and construction, which may be done at the flying field school and in the shop. Nor is there any charge for breakage as a result of the fault of a pupil.

Aviators' Certificates.—When you graduate you are given a certificate as to your ability as a flyer, and this means that you will be accepted everywhere as a competent pilot; in fact, when you fly your final test you qualify for your certificate under as rigid conditions as those imposed on United States Army officers, except as to the long cross-country flights.

What It Costs.—It costs $1.00 a minute to learn to fly. The tuition fee is $400.00 or $500.00, payable

in advance, and, as stated above, if you should not show aptitude or it is deemed advisable for any other reason the companies reserve the right of returning the amount paid and of canceling the instruction. If you want to join the United States Flying Corps the Government will pay your tuition and expenses while you are learning to fly, that is, if you are accepted.

Service in the U. S. Flying Corps.—The necessary procedure to be followed by a civilian in order to become a pilot in the *Aviation Section, Signal Officers' Reserve Corps* is given in *General Orders, No. 55,* recently issued by the War Department, which is herewith reprinted.

General Orders
No. 55.

WAR DEPARTMENT,
Washington, October 16, 1916.

TENTATIVE SYSTEM FOR THE GENERAL ORGANIZATION OF THE AVIATION, SIGNAL CORPS

Aside from the officers and enlisted men of the Regular Army, the aviation personnel will consist of civilians employed by the Aviation Section of the Signal Corps, reserve officers, enlisted men of the Enlisted Reserve Corps, and National Guard organizations mustered into the service of the United States.

As far as flying is concerned, nearly all the personnel must be trained from uninstructed material. This also applies, to a great extent, to mechanicians and chauffeurs.

In general, the central office will provide for three divisions of duty.

First.—The provision of adequate material, such as aëro-

planes and their accessories. This involves the preparation of specifications for the material and its inspection under the inspection department of the central office. The inspection department in future is intended not only to reach all manufacturing plants and producers of material, but also all materials in the hands of tactical units.

Second.—A system by which the personnel will be trained. This involves a school system for the officers and a training system for the men in both civilian and military institutions.

Third.—The establishment of tactical units, their administration and supply.

The first will be handled by the central office through its technical departments, and issues of supplies ordered when and where necessary.

The second will be decentralized, as far as possible, but will be under the general jurisdiction of the central office in the same manner as other military educational institutions and service schools are under the War Department. There will be two general categories of schools: (a) The United States Army Aviation Schools (such as the one now at San Diego, Cal.), whose number, for the time being at least, is intended to be 3, that is, 1 for the Pacific coast, 1 for the Central States, and 1 for the East; (b) civilian schools maintained by manufacturers or others, which may be utilized for preliminary training purposes.

The country will be divided into three school districts. The commanding officer of the school at San Diego will have general jurisdiction over all the schools in the Western Department; the commanding officer of the school in the central part of the country will have jurisdiction over all the schools in the Central and Southern Departments, and the commanding officer of the school in the East will have jurisdiction over all the schools in the Eastern Department.

It is intended to send aviation personnel for all formations, except those of the Regular Army, to civilian aviation schools to obtain their preliminary instruction, after which they may

finish their course at the Army aviation schools and obtain their military aviators' rating.

The civilian schools will be handled along the following lines:

(a) A type of training machine will be prescribed by the Government for the use of the schools; (b) the schools will be given a certain compensation for the instruction of such personnel as may be assigned to them—this reimbursement will include the average breakage and will be paid when the student satisfactorily completes the course; students before assignment to a civilian school will be subjected to an examination by a board to determine their physical, mental and moral qualifications to take the course.

Having completed their instruction, the students will be available for commissions as reserve officers and assignment to units or other duty.

Military Departments.—Each department will have an aviation officer, to be designated as such, on the staff of the department commander. The aviation officer, under the department commander, will have general supervision over all aviation personnel and stores (with the exception of aviation schools, testing grounds and general supply depots of aviation material) within such department; the general control of all officers, men and civilian employees of the aviation section within the department; the instruction and equipment of all tactical units of heavier-than-air and lighter-than-air craft; the preparation of requisitions for the proper supply of aëro units in his department; the plans for the creation of new aëro units within the department, both in the Regular Army and the reserve of the Regular Army, and all other matters affecting the aviation section, including lists of the personnel of the Aviation Section, Signal Officers' Reserve Corps and the Enlisted Reserve Corps, Aviation Section, Signal Corps.

When this system is fully put into effect, the aviation officers of the various departments will remain the same in peace and war, and the organization will be capable of rapid ex-

cers and 20 men) would move off into the field, leaving behind them their respective depots, which depots could be moved wherever necessary, and personnel supplied directly to them from the school and depot systems.

The above indicates merely a general plan to be followed, as it is not deemed expedient to specify minute details to too great an extent at present. To begin with this system will be put into effect by the issuance of orders and directive letters to the various officers concerned. Later when all of the points have been tried out, these matters may be incorporated into Army Regulations.

Personnel will be obtained for the Aviation Section, Signal Corps, United States Army, as now prescribed by law and Army regulations.

Personnel for the Aviation Section, Signal Officers' Reserve Corps, under section 37, national defense act, will be obtained as prescribed in General Orders, No. 32, War Department, July 28, 1916, and as per appendix A, herewith.

Personnel for the Enlisted Reserve Corps, Aviation Section, Signal Corps, under section 55, national defense act, will be obtained as prescribed in appendix B, herewith.

Requirements for civilian aviation schools are contained in appendix C, herewith.

The method by which officers and men of the National Guard may be detailed for duty at aviation schools under section 99, national defense act, is mentioned in appendix D, herewith.

APPENDIX A

Requirements for Service in the Aviation Section, Signal Officers' Reserve Corps

1. Authority has been given by the Secretary of War for the organization of the Aviation Section, Signal Officers' Reserve Corps. The section may consist of 296 officers. The grades in said section shall be in the same proportion as those obtaining in the Aviation Section of the Signal Corps, United States Army, up to include the grade major. Unless especially authorized by the officer in charge of the aviation section, all successful applicants for commissions in the Aviation Section, Signal Officers' Reserve Corps, will be commissioned in the grade of first lieutenant.

2. Any male citizen of the United States, not under 21 nor over 30 years of age, desiring a commission in the Aviation Section, Signal Officers' Reserve Corps, will submit a letter in the following form to The Adjutant General, United States Army; to the adjutant of the department in which the applicant lives, or to the officer in charge of the Aviation Section, Signal Corps of the Army:

Letter of application for Examination for Commission in Officers' Reserve Corps.

(Under section 37, act of June 3, 1916.)

................., ..., 19..

The ....

Sir: I have the honor to apply for examination for a commission as [1].......... of [2]........ [3].................. in the Officers' Reserve Corps, organized under the authority of Congress.

I have served .... years in [4]................

I have pursued a regular course of instruction for .... years in [5]................

I graduated in the year .... from [6]................ after having creditably pursued the course of military instruction therein provided.

I was born ...., ..., and am [7]...... a citizen of the United States. My business is ....

My experience is .... I enclose letters of recommendation and addresses of citizens who know me as follows: ....

Respectfully,

....

....

The correctness of the statements above made was sworn to and subscribed before me, ..., 19....

[8]..............................

....

1. Insert grade.

2. Insert branch of service, staff corps, or department, as Cavalry, Field Artillery, Coast Artillery, Infantry, Quartermaster Corps, etc.

3. Name staff position, and in this case rule out 1 and 2.

4. Insert service in Regular Army of the United States, or Volunteer forces of the United States, or Organized Militia of any State, Territory, or District of Columbia; also state in what capacity.

5. Insert name and location of school or college.

6. Insert the name and location of the educational institution in which an officer of the Army or Navy has been detailed as superintendent or professor pursuant to law.

7. Insert "not" if in accordance with fact.

8. Oath to be taken before, and signature to be made by, officer authorized by law to administer oaths.

Note.—The foregoing is the form to be followed in applying for examination and is to be addressed to the adjutant of the department in which the applicant lives, the Adjutant Gen-

eral of the Army, or the head of the staff corps or department concerned.

The communication authorizing the examination of the applicant will be sufficient authority when submitted to the president of the examining board before which the applicant will be ordered to appear. This board will consist of from two to five commissioned officers of the Regular Army of the United States, or of regular and reserve officers of the Signal Corps, including at least one and not more than two medical officers, at least one officer of the Regular Army will serve on each board. This board will be appointed on the recommendation of the officer in charge of the Aviation Section of the Signal Corps of the Army.

Each applicant will be subjected to the same physical examination as is required of an officer of the Regular Army applying for aviation duty. Applicants will not be examined mentally, but the equivalent of a college education will be required. The examining board will consider documentary evidence submitted by the applicant. It may seek additional information by practical tests, personal questions, or by procuring additional documentary evidence. Flying ability will be given first consideration, noted and reported in the proceedings of the board. No applicant for a commission as an officer in the Aviation Section, Signal Officers' Reserve Corps, will be considered proficient until he is able to pass the flying test for Reserve military aviator, unless specially excepted for reasons stated by the officer in charge of the Aviation Section, Signal Corps of the Army.

After the required examination the proceedings of the board will be forwarded to the headquarters of the convening authority, with the recommendations of the board as to the qualifications of the applicant. The officer in charge of the Aviation Section, Signal Corps of the Army, will recommend to the Adjutant General the grade in which each candidate should be commissioned. After appointment by the President, the Adjutant-General will issue the commission. The commissions

of the officers of the Officers' Reserve Corps will be in force for a period of five years, unless sooner terminated at the discretion of the President. Such officers may be recommissioned either in the same or higher grades for successive periods of five years, subject to such examination as may be prescribed.

In time of actual or threatened hostilities, officers of the Officers' Reserve Corps are subject to such duty as the President may prescribe. The officer in charge of the aviation section, when authorized by the Secretary of War, may order reserve officers for duty for periods not to exceed 15 days a year, and while so serving such officers will receive the pay and allowance of their respective grades in the Regular Army.

With the consent of the reserve officers concerned, and within the limits of funds available for the purpose, officers of the Officers' Reserve Corps will be retained on active duty for such periods as the Secretary of War may prescribe.

In order to qualify for examination as officers of the Aviation Section, Signal Officers' Reserve Corps, especially qualified citizens of the United States not under 21 nor over 27 years of age will be assisted by the United States as follows: To become eligible for obtaining such instruction, the person desiring it shall make application to the officer in charge of the Aviation Section, Signal Corps, who, if the applicant is considered desirable, will cause such applicant to be examined by the same board convened for the examination of officers of the Aviation Section, Signal Officers' Reserve Corps, which board will pass on the applicant's physical, mental, and moral qualifications. The physical test shall be the same as that required for officers of the Aviation Section of the Signal Corps. In the mental test the applicant will be required to establish the fact that he has the equivalent of a college education. The moral test will require the applicant to establish his reliability and good habits. The candidate will be required to state in writing that if he successfully passes his aviation tests he will become an officer in the Aviation Sec-

tion, Signal Officers' Reserve Corps. If the candidate successfully passes, the board will so recommend to the officer in charge of the Aviation Section, Signal Corps. The officer in charge of the Aviation Section, Signal Corps, will then designate the applicant as an aviation student. If the student desires to enlist in the Aviation Section of the Enlisted Reserve Corps, he will be made a noncommissioned officer and placed on active duty up to the time his course is finished and he is discharged to accept a commission in the Aviation Section, Signal Officers' Reserve Corps. If he fails in his course, he may apply for his discharge from the Aviation Section of the Enlisted Reserve Corps. If the student does not desire to enlist he may attend the course as a civilian at his own expense. The aviation student will then be assigned by the officer in charge of the Aviation Section to a school for his instruction. Such school may be either a United States aviation school or a civilian aviation school. The civilian aviation school will be one approved by the officer in charge of the Aviation Section, Signal Corps, as to instructors, machines used, and character of instruction given. The civilian schools shall receive $500 for each aviation student who qualifies for the preliminary flying test, the test to be conducted by an officer or agent of the Aviation Section of the Signal Corps. For any aviation student who qualifies as a reserve military aviator upon graduation from a civilian aviation school an additional $300 will be paid to such school. Upon the candidate satisfactorily passing the reserve military aviator's test he will receive a commission as an officer in the Aviation Section, Signal Officers' Reserve Corps, without further examination.

It is the intention gradually to organize reserve aëro squadrons in various parts of the country from the commissioned and enlisted reserve personnel.

APPENDIX B

Requirements for Service in the Enlisted Reserve Corps, Aviation Section, Signal Corps

Qualifications

1. *General Requirements.*—Service in the Enlisted Service Corps, Aviation Section, Signal Corps, is by enlistment. Applicants must not be under 18 nor over 45 years of age. They must be of good antecedents and habits and free from bodily defects and diseases. They must be citizens of the United States or have made legal declaration of their intention to become citizens of the United States and be able to speak, read, and write the English language. Before enlisting, they are required to pass physical examination to determine their fitness for service in the United States Army. Before authority for enlistment is granted the applicant will furnish two or more certificates of good moral character. As the service is technical, men qualified as aviators, balloonists, or mechanicians, who have had experience in the construction and repair of aëroplanes or internal-combustion engines, are particularly desirable.

2. Following are the numbers authorized in each grade:

(1)	54	master signal electricians.
(2)	190	sergeants, first class.
(3)	271	sergeants.
(4)	543	corporals.
(5)	1,381	privates, first class.
(6)	276	privates.
	2,715	total.

3. Qualifications for enlistment direct into each of these grades are as follows:

(1) Candidates must have a working knowledge of gasoline motors, magnetos, carburetors, telegraphy, and a fair knowledge of the principles of electricity and photography.

(2) Working knowledge of motors, magnetos, and carburetors.

(3) and (4) A general knowledge of subjects given under (1) and (2) and have sufficient training and interest to show that he is adaptable to work of this kind.

(5) Applicants must show an interest in subjects mentioned, be competent, and keen, to insure that they will develop along the proper lines in training.

When men enlist in any of the above grades, certificates of enlistment in the Enlisted Aviation Reserve Corps will be issued by the Adjutant General of the Army. The certificates will confer upon the holders, when called into active service or when called for purposes of instruction and training, and during the period of such active service, instruction, or training, all the authority, rights and privileges of like grades in the Regular Army. Members of the Enlisted Reserve Corps, Aviation Section, Signal Corps, shall take precedence in each grade of said corps according to dates of their certificates of enlistment therein, and when called into active service, or when called out for purposes of instruction and training, shall take precedence next below all other enlisted men of like grades in the Regular Army. The President is authorized by law to assign members of the Enlisted Reserve Corps, Aviation Section, Signal Corps, as reserves to particular organizations of the Regular Army. The Secretary of War is authorized by law to order enlisted men of the Enlisted Reserve Corps, Aviation Section, Signal Corps, to active service for purposes of instruction or training for periods not to exceed 15 days per year, provided that, with the consent of such enlisted men, and within the limits of funds available for such purpose, such periods of active service may be extended for such

number of enlisted men as may be deemed necessary. Enlisted men will receive the pay and allowances of their respective grades in the Regular Army, but only when ordered into active service, including the time required for actual travel from their homes to the places to which ordered and return to their homes.

4. *Rates of Pay.*—The grades and pay of the enlisted force of the Aviation Section, Signal Corps, United States Army, are as follows:

	While serving in the U. S., Hawaii, Porto Rico, or the Canal Zone. Per month	While serving in Alaska, China, or the Philippines. Per month
Master signal electricians	$75.00	$90.00
Sergeants, first class	45.00	54.00
Sergeants	36.00	43.20
Cooks	30.00	36.00
Corporals	24.00	28.00
Privates, first class	18.00	21.60
Privates	15.00	18.00

In addition to the above there will be a slight increase per month after each enlistment period of four years. All enlisted men, in addition to their regular pay, receive rations, quarters, clothing, fuel, bedding, medicine, and medical attendance when required.

When called into active service of the United States members of the Enlisted Aviation Reserve Corps will receive the rate of pay corresponding to their grade.

5. *Retirement.*—Enlisted men of the Aviation Reserve Corps will not be entitled to retirement or to retired pay, nor will they be entitled to pension except in case of physical disability incurred while on active service or while traveling under orders of competent authority to or from designated places of duty.

6. *Uniform.*—The uniform to be worn by the enlisted men of the Enlisted Reserve Corps, Aviation Section, Signal Corps, except corps insignia, shall be the same as prescribed for enlisted men of the Aviation Section, Signal Corps of the Regular Army Reserve. In time of peace there shall be issued to each enlisted man of the Enlisted Reserve Corps, Aviation Section, Signal Corps, such articles of clothing and equipment as may be prescribed. All clothing and equipment shall remain the property of the United States.

7. *Term of Enlistment.*—The term of enlistment is four years.

APPENDIX C

Requirements for Civilian Aviation Schools

(An inspection will be made by an officer of the Aviation Section of the Signal Corps to determine whether the requirements are fulfilled.)

1. *Field.*—The field should be of sufficient size and shape to permit of landing and getting away in at least two different directions under normal conditions. The ground must be fairly level and free from obstructions of all kinds. These requisitions will be determined on inspection by an officer or agent of the Aviation Section of the Signal Corps.

2. *Training Machines.*—The training machines will comply with the specifications prescribed by the Aviation Section for the preliminary and advanced training types. These specifications will be furnished all civilian schools that instruct students for the Government, or desire to do so.

3. *Instructors.*—Instructors must be men of experience in flying and thoroughly competent to teach through the reserve military aviator stage. They should be level-headed, have good judgment, and sufficient mental balance to impart what they know.

4. *Character of Instruction.* The course of instruction will be divided into two stages. The first stage will include instruction and qualification through and to include the preliminary flying test. This test will be held under the supervision of an officer or agent of the Aviation Section of the Signal Corps. The second stage, which is optional with the school authorities, will consist of advanced training necessary to qualify an aviation student as a reserve military aviator. An advanced

training type of machine will be used at least during the last stages of this instruction. Detailed information as to the course to be followed in this stage will be furnished the school authorities. The reserve military aviator test will be held under the supervision of an officer or agent of the Aviation Section of the Signal Corps.

5. *Preliminary Flying Test.*—(a) Three sets of figure eights around *pylons* 1,600 feet apart. In making turns around pylons all parts of the machine will be kept within a circle whose radius is 800 feet.

(b) Stop motor at a minimum height of 300 feet and land, causing machine to come to rest within 150 feet of a previously designated point.

(c) An altitude test consisting of rising to a minimum height of 1,000 feet.

(d) Glides with motor throttled, changing direction 90 degrees to right and left.

Note.—(a) and (b) may be executed in one flight; (c) and (d) in one flight. The same rules apply in starting from or landing on water. Special attention will be paid to the character of landings made.

Should any aviation student desire to take the pilot license test prescribed by the Aëro Club of America, every facility will be offered for him to do so.

Report of these tests will be submitted to the officer in charge of the Aviation Section, with the information as to whether or not the school will complete training of the aviator through the reserve military aviator stage.

6. *Reserve Military Aviator Test* will be as follows:

(a) Climb out of a field 2,000 feet square, and attain 500 feet altitude, keeping all parts of machine inside of square during climb.

(b) Glides at normal angle, with motor throttled. Spirals to right and left. Change of direction in gliding.

(c) At 1,000 feet, cut off motor and land within 200 feet of previously designated point.

(d) Land over an assumed obstacle 10 feet high and come to rest within 1,500 feet from same.

(e) Cross-country triangular flight of 30 miles, passing over two previously designated points. Minimum altitude 2,500 feet.

(f) Straight-away cross-country flight of 30 miles. Landing to be made at designated destination. Both outward and return flight at minimum altitude of 2,500 feet.

(g) Fly for 45 minutes at an altitude of 4,000 feet.

7. *Pay for Tuition.*—Upon the student passing the preliminary flying test satisfactorily the school will be paid $500. If the student is continued under instruction until he satisfactorily passes the reserve military aviator test, an additional $300 will be paid the school.

8. All candidates for the Aviation Section, Signal Officers' Reserve Corps, will be required to pass the prescribed physical examination, must weigh not more than 190 pounds, stripped, must furnish evidence of having a college education, and be of good moral character.

9. Applicants for commissions as reserve officers who hold the pilot certificate of the Aëro Club of America, will, after successfully undergoing the prescribed physical examination, be given a flying examination embodying at least the requirements of the preliminary flying test. If competent, they may also take the reserve military aviator's test.

If the preliminary flying test is passed satisfactorily and a candidate qualifies in other respects, he will be eligible for further instruction to qualify as a reserve military aviator.

If, in addition to the preliminary flying test the candidate also passes the reserve military aviator's test satisfactorily, he will be given a commission in the Aviation Section, Signal Reserve Corps, provided all other qualifications are fulfilled.

APPENDIX D

Detail of Officers and Enlisted Men of the National Guard at Signal Corps Aviation Schools

Officers and enlisted men of the National Guard may be detailed at Signal Corps aviation schools under section 99 of the national defense act. National Guard officers and men desiring such course will apply to the adjutant general of their State, who will forward the application direct to the Chief, Militia Bureau, War Department, Washington, D. C. Such officers and enlisted men will be required to pass the prescribed physical and mental examinations, which will be similar to those required of reserve officers, Aviation Section, Signal Officers' Reserve Corps. On approval by the Militia Bureau, orders will be requested from the Adjutant General of the Army assigning such officers or enlisted men to duty at aviation schools. (2446404 A.G.O.) By order of the Secretary of War:

H. L. Scott,
Major General, Chief of Staff.

Official:
H. P. McCain,
The Adjutant General.

Location of Flying Schools.—The Wright Flying Field is located at Hempstead Plains, Long Island, N. Y. It is one of the internationally known great flying fields. Here and at Dayton, Ohio, practical aviation began in this country.

The instructors are under the command of Howard L. Rinehart, a pilot who has been flying Wright standard and experimental machines for many years, and learning to fly with

him is safer than crossing Fifth Avenue at Forty-second Street.

The school office and field is within walking distance of either Garden City or Mineola stations (Long Island), and either of them is about an hour's ride out of New York City. Address Wright Flying Field, Inc., 60 Broadway, New York City.

The Curtiss Training School.—Two schools are maintained throughout the winter months by the Curtiss Company, one at Newport News, Va., and the other at Miami, Florida.

During the summer months they also keep a school at Buffalo, New York; this generally opens some time in May and closes about the first of November. For terms, particulars, etc., address The Curtiss Exhibition Company, Churchill St., Buffalo, N. Y.

Other Flying Schools.—There are other good flying schools, though not as noted as the above named ones. Among these are:

The America Trans Oceanic Company, 280 Madison Avenue, New York, conduct a summer flying field at Port Washington, Long Island, New York, and a winter flying field at Palm Beach, Florida.

The Staten Island Aviation School has a private flying field at Graham Beach, adjoining Midland Beach, Staten Island, New York City. Address 119 Lexington Avenue, N. Y. C.

The Bean School of Aviation, at Celina, Ohio, and

The Williams Aviation School, at Fenton, Michigan.

CHAPTER VIII

HOW AËROPLANES ARE USED IN WAR[1]

The present great conflict in Europe has shown that aëroplanes are an absolutely necessary aid to the operations of field artillery and the defense of naval squadrons.

The services performed by the aid of aëroplanes are: (1) general scouting work, that is, to determine the enemy's position, strength and purposes; (2) for preventing hostile scouting aëroplanes from reconnoitering and for testing the concealment of hostile batteries; (3) for destroying hostile aircraft and for offensive work against submarines and other vessels of the enemy; (4) for aiding artillery fire on the enemy's batteries and trenches by land and in spotting the fire against ships and against any invading force that might invest the fortifications; and (5) for carrying guns, dropping bombs and other kinds of offensive work against the enemy.

Kinds of Warplanes.—For these varied services three types of aëroplanes are used, and these are: (a)

[1] Based on *Military Aviation*, a document prepared by the Army War College, Washington.

PERFORMANCE REQUIRED FROM VARIOUS MILITARY WARPLANES

	Light Scout Aëroplane	Reconnaissance Aëroplane (a)	Reconnaissance Aëroplane (b)	Fighting Aëroplane (a)	Fighting Aëroplane (b)
Tankage to give endurance of	300 miles	300 miles	200 miles	200 miles	300 miles
To carry.......	Pilot only	Pilot and observer plus 80 pounds for wireless equipment	Pilot and observer plus 80 pounds for wireless equipment	Pilot and gunner plus 300 pounds for gun and ammunition	Pilot and gunner plus 100 pounds
Range of speed.	50 to 85 miles per hour	45 to 75 miles per hour	35 to 60 miles per hour	45 to 65 miles per hour	45 to 75 miles per hour
To climb 3,500 feet in	5 minutes	7 minutes	10 minutes	10 minutes	8 minutes
Miscellaneous qualities	Capable of being started by the pilot single-handed	....	To land over a 30 foot vertical obstacle and pull up within a distance of 100 yards from that obstacle, the wind not being more than 15 miles per hour. A very good view essential.	A clear field of fire in every direction up to 30° from the line of flight	A clear field of fire in every direction up to 30° from the line of flight

Aëroplanes for instruction with an endurance of 150 miles will also be tested under special conditions; safety and ease of handling will be of the first importance in this type.

high-speed machines for long-distance scouting and combating the enemy's aircraft; (b) ordinary speed machines for general scouting and for observing the fire of artillery; and (c) battle planes equipped with machine guns for dropping bombs and for the destruction of the enemy's men, material and equipment.

The following table published by the *London Times* at the outbreak of the war gives the necessary requirements of each type of machine at that time, and they still prevail, though the speed and the radius of action have been considerably increased.

Height of Flying Warplanes.—In order to escape the fire of small arms aëroplanes must fly at a height of about 4,000 feet above the ground, but when *balloon guns* were invented this height had to be increased to 6,000 feet and machines must now fly at this height in order to be reasonably safe from being hit by hostile projectiles.

When flying at the latter height it is hard for even a trained officer to take in the small details or to see the fitness of the enemy's position, but bridges, trains, large columns of troops, artillery firing, etc., can be readily made out.

Aëroplane Scouting.—Where in past wars scouting, or *strategical reconnaissance,* as it is called, was carried out by reconnoitering troops or captive balloons, nearly all of this kind of work is now done by aëroplanes.

Besides the pilot the aëroplane must carry a trained strategical expert, because an ordinary aviator would not be able to give the proper military value to the indistinct objects on the earth below him. The expert is a tactical officer and the pilot is either an officer or a non-commissioned officer.

Photographing the Enemy.—In these aërial scouting expeditions the camera, too, plays an important part. It is so arranged that one or a number of consecutive pictures[1] can be made of the enemy's territory.

The films are quickly developed on the return of the aëroplane, lantern slides are made of them, and the pictures are thrown on a screen by a stereopticon, when all the details are highly magnified and those that were too small to be seen with the naked eye are brought out plainly. These details are then entered on the maps used by the officers.

How Aëroplanes Direct the Fire.—The way in which war is now carried on makes it impossible to locate the fire of the enemy's artillery from the ground, because of the way in which it is hidden in the trenches, etc.

Here again the aëroplane becomes an indispensable arm of the service for observing the fire and directing

[1] Cameras for aircraft work can be obtained of Arthur Brock, Jr., manufacturer of specified equipment of U. S. Army Aviation Section Signal Corps, 511 Bullet Building, Philadelphia.

it, and the way it is done is like this: First they pick up the targets, next report their location to the field artillery, and then observe the fire.

The aëroplanes then signal either by some means such as flags, or by wireless telegraphy, to the battery where to fire to make itself felt.

Gun Carrying Aëroplanes.—The armored fighting aëroplane carries a rapid-fire gun mounted in the bow where it will have a clear range of fire in either direction up to 30 degrees from the line of flight.

The Lewis Machine Gun.—A light type of machine arm that has been found very effective for fighting aëroplanes is the *Lewis automatic machine gun,* and it has proved a vital factor in the European war.

It is really an automatic pistol on a large scale, weighing in the neighborhood of 26 pounds, and it can get into action just as quick and is just as mobile as the smaller hand arm, since it can be operated in any position, firing straight up or straight down, or it can be fired when turned on either side or upside down.

Its rapidity in firing is due to the use of detachable drum-shaped rotating magazines. Each magazine holds 47 or 97 cartridges, and when one is latched on the magazine post it becomes an integral part of the gun for the time being. The gun can then be fired continuously until the magazine is empty, when it is snatched

off and another snapped on as quickly as an empty magazine is dropped out of an automatic pistol and a loaded one put in.

The operation of this gun is very ingenious. In the first place it is air-cooled; to provide a large enough cooling surface and a sufficient quantity of air at a high enough velocity the barrel is surrounded with a radiator having thick, high radial fins made of aluminum, which extend its entire length.

The radiator is inclosed in a thin steel tube open at both ends and extending beyond the muzzle. When the gun is fired the muzzle blast acts like a suction pump on the radiator tube at the muzzle, and this pulls a stream of fresh air through the grooves between the radiator fins every time a shot is fired. When the gun is fired continuously a steady column of air is pulled through the radiator at a high velocity, and this carries off the heat developed in the barrel.

The power to fire the gun is had by letting the powder gas from a small hole, or *port,* as it is called, in the barrel near the muzzle escape into a cylinder under the barrel in which a piston is fitted. The latter is driven back by the expanding gas and this opens the *action.*[1] This in turn unlocks and withdraws the breech bolt, the fired shell is extracted and ejected, a cartridge is carried by the feed arm from the magazine into the

[1] The *action* of a gun is the mechanical part of it between the stock and the barrel.

feeding position in the receiver,[1] the magazine is rotated a notch and locked, and the main spring is wound up.

If now the trigger is held back the closing stroke of the action instantly follows the opening stroke, and the firing of the gun is automatic and continuous as long as there are cartridges in the magazine. But if the trigger is not held back the gun will remain in a *ready-to-feed* position with the action open and the chamber empty.

The power of the closing stroke is supplied by the main spring, which rotates the gear and makes the breech bolt drive the cartridge into the receiver ahead of it in the chamber, the bolt is *cammed*—that is, turned—around the lock, the extractors take hold of the rim of the cartridge, the feed arm is returned to its former position, and finally at the end of the stroke the striker hits the primer of the cartridge and fires it. The instant the bullet gets past the gas port in the barrel the opening stroke commences.

In 1912 Col. Lewis, U. S. Army, retired, brought four of his guns to Washington, where tests were made before the Secretary of War and officers of the Army.

At this time a notable test was made when the gun was fired from an aëroplane in full flight, at the Signal Corps Aviation School at College Park, Maryland. This was the first time that a machine gun had ever been so

[1] The *receiver* is the case which contains the action.

fired from an aëroplane, and it marked a new era in aërial warfare. Figure 65 shows how the Lewis machine gun is mounted on the bow of the body of the aëroplane.

The Lewis gun has been adopted by the British Government in the Royal Flying Corps, and over 40,000

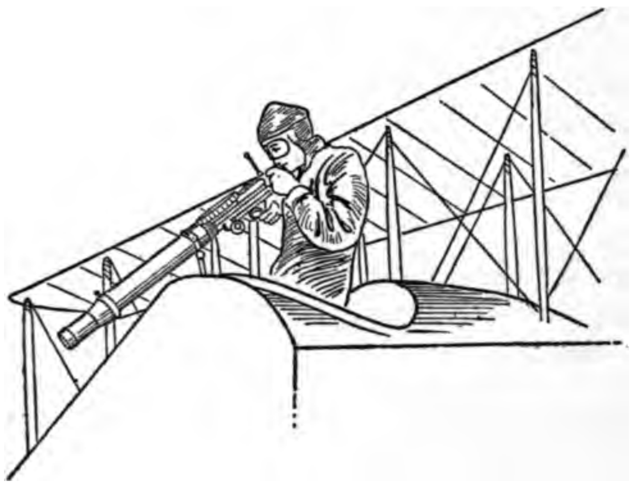

FIG. 65.—A U. S. BATTLEPLANE WITH A LEWIS MACHINE GUN MOUNTED ON THE BOW

have entered service in the Allied armies of the Entente Powers since the beginning of the war. It is also used by the Army and Navy of the United States. It is manufactured by the Savage Arms Company, and you ought to get acquainted with it.

The Davis Non-recoil Gun.—There are two things that determine the power of a gun which can be used

on aëroplanes, and these are: (1) its *weight;* and (2) the *force* of its *recoil.*

To the end that a heavier projectile can be fired than is usual with rapid-fire guns the Davis non-recoil gun was invented, and though it sounds like a paradox it is nevertheless a fact that however large the caliber of the gun and whatever the weight of the projectile, there

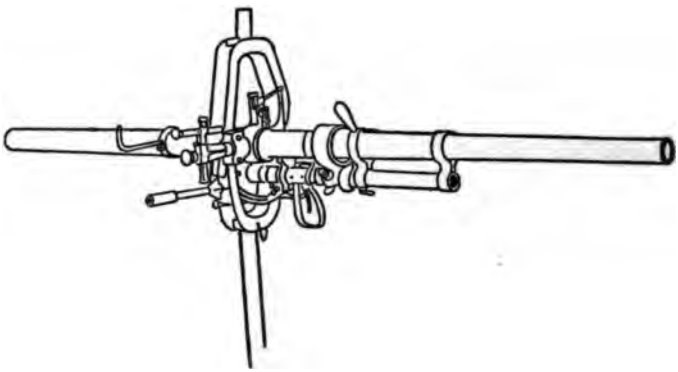

FIG. 66.—THE DAVIS NON-RECOIL GUN

is no recoil force developed by it. Hence the weight of the gun becomes the only factor that need be considered.

In order to make a gun in which the recoil is suppressed two barrels in alignment are used instead of one, and when the projectile is fired from the main and front barrel a charge of shot is fired simultaneously from the second and rear barrel.

The charge of shot fired is of exactly the same weight

as the projectile, and this being the case one discharge counteracts the recoil of the other discharge, with the result that a man can hold it on his shoulder while it is being fired, without any other support whatever, and the gun will not move to any appreciable extent. It is shown in Fig. 66.

The weight of the non-recoil gun has been reduced to 103 pounds complete for the 6-pounder and 238 pounds complete for the 12-pounder. As I write, 500 men are at the present time engaged at the plant of the General Ordinance Company, Derby, Connecticut, in making this type of gun for the Allied armies in Europe.

Bomb Dropping Aëroplanes.—Other machines carry bombs of various kinds, and these weigh anywhere from 2 to 50 pounds, though the most common ones weigh from 15 to 35 pounds. Dropping bombs from an aëroplane would seem to be a certain way to destroy the enemy's material, but owing to the height, and the speed with which an aëroplane must fly, and the deflection of the bomb by the wind, it is a very hard thing to hit an object.

The most successful way of doing it is to send a flotilla of from 30 to 60 machines, each of which carries from 5 to 10 bombs. These circle over the bridges, railways, or wherever the attack is to be made, and drop the bombs. Some of them are almost certain to hit the target.

Arrows.—Instead of dropping bombs the French devised a scheme which was even more effective for destroying troops on the march. This is a steel-pointed dart or arrow whose diameter and length are about those of a lead pencil.

These little death-dealing darts are dropped from an aëroplane in bundles of about 1,000 while the machine is flying at a height of a mile or so. They spread out over a considerable area and after falling from so great a height the arrows go clear through any and everything which they happen to hit.

Aëroplanes for Guarding Cities.—In Europe, where every city is liable at any time to an attack by bomb-dropping *dirigibles* or aëroplanes, a very swift type of machine is needed for guarding.

It is built to climb fast and to make high speed. As dependability and economy of operation are of small consequence in virtue of the fact that the flights are of short duration, and in case of necessity a landing can be made, little attention is paid to the latter factors. For high-speed aëroplanes of this type the revolving engine, which is the lightest made, is used exclusively.

U. S. Army Warplanes.—The following makes of aëroplanes have been adopted by the United States Army.

I have appended the names and addresses of the makers in order that you may write to them direct and

obtain detailed information concerning their respective machines, which they will send you free of charge.

Make	Maker	Address
Curtiss	Curtiss Aëroplane and Motor Co.	Churchill St., Buffalo, N. Y.
Aëromarine	Aëromarine Plane and Motor Co.	Nutley, N. J.
Standard		Jamaica Plains, L. I.
Sturtevant	Sturtevant Aëroplane Co	Boston, Mass.
Thomas	Thomas Bros. Aëroplane Co.	Ithaca, N. Y.

U. S. Army Seaplanes.—The only difference, as you have seen, between a seaplane and a flying boat is that the former is fitted with floats, while the latter has a hull.

By mounting an aëroplane on floats instead of on a hull, it can rise from, and ride, and alight on rough water, and hence this type of aircraft is especially valuable for sea maneuvering where a flying boat could not be used.

The development of the seaplane is due chiefly to Henri Fabre of France and Glenn H. Curtiss here at home, and through their initial efforts and genius they have added a new and mighty fighting machine to those already used on and under the sea and in the air in the present and future games of war.

Though Curtiss made the first experiments in 1909

with a seaplane, he was not entirely able to leave the water. The earliest successful flight of an aëroplane rising from and alighting on the water was made by Fabre in 1910 at Martigues, France.

Fabre's seaplane was a monoplane set on three floats with curved and hollow hulls and having elastic bottoms. These were attached by flexible members to the body of the machine. In the first trials the seaplane skimmed along the water at a high speed and left the surface when it was going at the rate of 34 miles an hour. It flew at a height of from 5 to 10 feet and at a distance of about a third of a mile, and then it alighted on the water again.

Very shortly after Fabre's achievement with his seaplane Curtiss made a series of spectacular experiments at San Diego, California, in which he repeatedly rose and alighted on the water.

Curtiss fitted this seaplane with a large float made very much like a narrow flat-bottom boat and covered over the top with canvas to keep the water out. It was set with its bottom at a slight angle to the surface of the planes; that is, the nose of the float was tilted up a little.

The float was joined to the under part of the middle of the lower wing by a strong framework. To keep the seaplane from dipping too far to one side or the other he attached a stick to each end of the lower main plane at a slant, and to give the machine greater buoyancy

an inflated rubber tube was fastened between the ends of the stick and the plane.

In one of his earliest flights he made a trip from North Island, where he had his proving grounds, to the U. S. S. *Pennsylvania,* a cruiser anchored at the time in San Diego Harbor. He brought his seaplane close to the side of the cruiser and gently alighted on the water; then he and his seaplane were hoisted aboard the ship and the first seaplane navigator was congratulated by the officers.

A little later Curtiss was lowered in his seaplane to the sea; one of the cruiser's jackies spun the propeller to set the engine going, and the pioneer of water flying got his machine under way and flew back to his island again.

In another trial after enlarging the wings of his seaplane the pilot flew with a passenger. The passenger was an officer of the *Pennsylvania,* and while the pilot sat in the body the officer took his place on the float.

When at a little height the officer could see into the clear water just as though he was looking through a glass-bottomed boat, and this gave the War Department the hint that the seaplane would not only be useful for dropping bombs on enemy warships, but also for locating and destroying submarines.

Gigantic seaplanes are now made with twin engines and are able to rise from the water within 50 feet after starting. Fig. 65 shows a Wright-Martin seaplane at

close range. The following table gives the make and the maker's name and address of seaplanes used by the U. S. War Department:

U. S. NAVY SEAPLANES

Curtiss	Curtiss Aëroplane and Motor Co.	Buffalo, N. Y.
Burgess	The Burgess Co.	Marblehead, Mass.
Gallaudet	Gallaudet Co.	Norwich, Conn.
Sturtevant	Sturtevant Aëroplane Co.	Boston, Mass.
Thomas	Thomas Bros. Aëroplane Co.	Ithaca, N. Y.
Standard		Jamaica Plains, L. I.

Warplanes Used on European Battle Fronts.—The following makes of warplanes are prominent at the present time on the various European battle fronts and include aëroplanes, seaplanes, and flying boats:

GREAT BRITAIN

Avro	Handley-Paige
British Speed Scout	Short
Caudron	Sopwith
Grahme-White	Vickers
Rep	

All the above are biplanes except the Bristol Speed Scout and the Rep; all are single-motored except the Caudron; and all are tractors except the Vickers.

FRANCE

Voisin	Nieuport
Twin-motored Caudron	Morane
Farman	Deperdussin

The Nieuport, Morane and Deperdussin are monoplanes, and the Voisin and Caudron are biplanes.

The Caudron is engined with twin Gnome and Anzani revolving engines, each one being mounted in a little *nacelle* which also serves the purpose of supporting the fuel tanks and enclosing them in a stream line body.

Both pilot and observer are seated in a center *nacelle,* from which they can get a very good view forward and around. The main planes have a flexible trailing edge, and the elevators are of the usual hinged divided type.

GERMANY

Fokker	Twin Engine Hun
Gotha	L. V. G.
Lohner	Rumpler

The following data concerning German machines have been chiefly gathered by the French aviators who captured them.

Of these the *Fokker* is the best known. These machines are generally single seaters and hence the pilot is also the gunner. Most Fokkers have two guns, one of which is fired through the propeller, and the other is mounted on the beam.

In order that the pilot can use the gun without hindrance there is a device with which he can lock the elevator control, and he steers to the right or left with his feet on a rudder bar.

The machine gun is of the Maxim type, and is im-

movably fixed above the engine cowl and a little to the right. This being the case, he aims not with his gun, but with the whole machine, a method by no means easy if the target is to be hit.

The *Gotha* is a tractor hydroplane; the *Hun* is twin-engined, very much like the Caudron, and is also a hydroplane; while the *Lohner* is a flying boat.

The L. V. G. is a battleplane. Before the war it was a noted aëroplane racer, and it has proved a very successful fighting plane as well. It is largely used for reconnoitering, and it is said that it is the best machine the Germans have for this kind of work.

As a fighter it is fitted with the Lewis machine gun, with bomb throwers, flash signal devices, and star lights.

More *Rumpler* warplanes than any other kind have been captured by the French. The pilot's seat is in the forward cockpit over the main fuel tank. The observer or gunner sits in a seat in the rear cockpit with a machine gun and both guns are mounted so that they can turn on a circular track.

In the machines intended for dropping bombs a release gear is provided to drop six bombs. Only a light gun is carried in this type of machine for defense. Machines designed for destroyers are fitted with larger and more powerful guns.

The Mastery of the Air.—In the beginning of the war attempts were made by the Austro-German armies to gain *control of the air,* and they succeeded when they

began their campaign against the Russians with the result that the latter were practically wiped out. But by the spring of 1917 the Allies had definitely established their superiority, as was shown by their effective work in the great drive against the retreating Germans. High praise has been given to the work of the American aviators, whose skill and daring have contributed much to the success of the Allies.

Although guns are mounted on the ground they are not very effective in bringing down aëroplanes, and the only way to combat the machines is by attacking them with other machines while in the air. This means a battle royal. Whenever a flotilla makes the attempt to secure the mastery of the air battles are fought by warplanes at close range much in the same way they were fought by frigates in the days of John Paul Jones.

CHAPTER IX

SOME NOTES ON FLIGHT AND FLYING

Rules and Regulations for Obtaining a Pilot's Certificate.—The following rules and regulations governing the issue of *pilots' certificates* are those of the *Fédération Aéronautique Internationale* (International Aëronautical Federation), of which the Aëro Club of America is a member. These rules and regulations are reprinted here by courtesy of the *Aëro Club of America*, 297 Madison Avenue, New York City.

The Aëro Club of America may grant aëronautical and aviation pilots' certificates to persons who are over 18 years of age, citizens of the United States or citizens of a country represented in the F. A. I., with the permission of the representative organization of the applicant's nationality.

The following are the rules under which certificates are granted by the Aëro Club of America:

(1) A person desiring a pilot's certificate must apply in writing to the Secretary of the Aëro Club in America. He must state in his letter the date and place of his birth and inclose therein two unmounted photographs of himself, about 2½ inches by 2½ inches, to-

gether with a fee of five dollars. In case the applicant is a naturalized citizen of the United States he must submit proof of his naturalization.

(2) On the receipt of an application the Secretary will forward it promptly to the Contest Committee, which in case of an application for an aviator's certificate will designate a representative to supervise the test prescribed by the International Aëronautical Federation and will advise the representative of the name and location of the applicant to take the test.

(3) All applications for aviator's certificates must reach the Secretary a reasonable time in advance of the date that the applicant may be expected to take the required test.

(4) No telegraphic applications for certificates will be considered.

Applicants must be of the age of 18 years and must pass to the satisfaction of the properly designated representatives of the Aëro Club the tests prescribed by the F. A. I. as follows:

Aviator's Certificate.—(1) Candidates must accomplish the three following tests, each being a separate flight.

(A and B) Two distance flights consisting of at least 5 *Kilometers* (16,404 feet), each in a closed circuit without touching the ground or water, the distance to be measured as described below.

(C) One altitude flight during which a height of at

least 100 *meters* (328) feet above the point of departure must be attained, the descent to be made from that height with the motor cut off. A *barograph* must be carried on the aëroplane in the altitude flight. (See Appendix.)

(1) The landing must be made in view of the observers without restarting the motor.

(2) The candidate must be alone in the aircraft during the three tests.

(3) Starting from and landing on the water is only permitted in one of the tests A and B.

(4) The course on which the aviator accomplishes tests A and B must be marked out by two posts, or buoys situated not more than 500 meters (547 yards) apart.

(5) The turns round the posts or buoys must be made alternately to the right and to the left so that the flight will consist of an uninterrupted series of figures.

(6) The distance flown shall be reckoned as if in a straight line between the two posts or buoys.

(7) The landing after the two distance flights in tests A and B shall be made (a) by stopping the motor at or before the moment of touching the ground or water, and (b) by bringing the aircraft to rest not more than 50 meters (164 feet) from a point indicated previously by the candidate.

(8) All landings must be made in a normal manner

and the observers to report any irregularities. The issuance of a certificate is always optional.

Official observers must be chosen from a list drawn up by the governing organization of each country.

Seaplane Pilot's Certificate.—The tests to be accomplished by candidates for this certificate are the same as those given above, except that starting from and landing on the water is permitted for all the tests.

Licenses for Aviators.—These are issued at the option of the Contest Committee of the Governing Board of the Aëro Club of America, which allows the holder to act as pilot in events governed by the regulations of the F. A. I.

Expert Aviator.—The Aëro Club of America has established the grade of *Expert Aviator.* Holders of the *Expert Certificate* are permitted to fly over cities in straight flight, and the privilege of using Governor's Island, New York, as a temporary landing station is extended to them by Major-General Leonard Wood, U. S. Army, Chief of the Department of the East.

APPENDICES

APPENDIX A

THE BAROMETER AND THE BAROGRAPH

When you make an *altitude,* or high-flying test, a *barograph* should be carried so that there can be no question as to the height you reach.

In an ordinary barometer a long tube is filled with mercury, and this column of mercury always has a height of 31 inches at sea level. As you ascend the pressure of the air grows less and the mercury drops in the tube until at 500 feet above sea level it is only 30.43 inches and the higher you take it the lower it goes. The following standard table shows the height of the mercury in the tube at various altitudes.

STANDARD TABLE OF ALTITUDES

Height of Mercury in Tube in Inches	Altitude in Feet	Mercury in Inches	Altitude in Feet	Mercury in Inches	Altitude in Feet	Mercury in Inches	Altitude in Feet	Mercury in Inches	Altitude in Feet
31.00	0	28.28	2,500	25.80	5,000	23.54	7,500	21.47	10,000
30.43	500	27.76	3,000	25.33	5,500	23.11	8,000	21.08	10,500
29.88	1,000	27.26	3,500	24.87	6,000	22.69	8,500	20.70	11,000
29.34	1,500	26.76	4,000	24.42	6,500	22.28	9,000	20.32	11,500
29.80	2,000	26.28	4,500	23.97	7,000	21.87	9,500	19.95	12,000
								14.88	20,000

As a barometer tube 31 inches high is not a convenient instrument to carry around, an *aneroid barometer* is used instead. This kind of a barometer is a round hollow metal box with a thin, springy corrugated metal cover. The air is pumped out of the box and it is then sealed up.

A delicate set of levers is fastened to the inside of

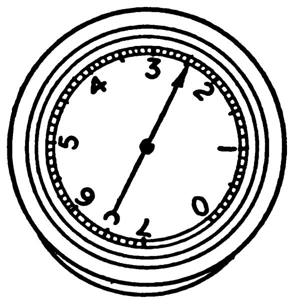

FIG. 67.—AN ALTITUDE BAROMETER FOR MEASURING ALTITUDES

the cover of the box and these move a needle or pointer over a scale marked off with the barometric readings in inches and the altitude in feet, just like the standard table of altitudes given above. See Fig. 67.

Now a *barograph* is made exactly like an aneroid barometer except that instead of a scale a piece of paper is fixed on a drum which is revolved by clockwork, and there is fixed to the end of the index needle a pen which marks on the moving paper every change in atmospheric pressure, and, therefore, the altitude the aëroplane has reached.

APPENDIX B

THE SPERRY SYNCHRONIZED DRIFT SET

In making a flight between two distant points separated by water or unfamiliar ground a pilot usually uses his compass in much the same way as a sailor uses a mariner's compass.

At any time during the trip he may find his bearings by plotting a line on his chart in the direction he has been traveling, and estimating his rate and time of travel give him the point on this line representing his apparent position at that moment.

This was the original plan for navigating the *America* on her proposed transatlantic trip. But considerable error is possible in steering by compass because no correction is made for *drift,* that is, having the line of flight varied by a side wind of unknown velocity.

This is shown in Fig. 68, in which the line indicated by the letters O and F is the direction in which the aëroplane is steering, and this would be the direction of travel if there was no side wind. The line OS represents the direction of the side wind, and its length bears the same relation to the length of O, the line OF,

as the velocity of the side wind bears to the speed of the aëroplane.

The line OR is the time direction in which the aëroplane is traveling. A side wind of 10 to 25 miles an hour may often be encountered and in a six or eight hours' flight the aëroplane may have drifted so far from

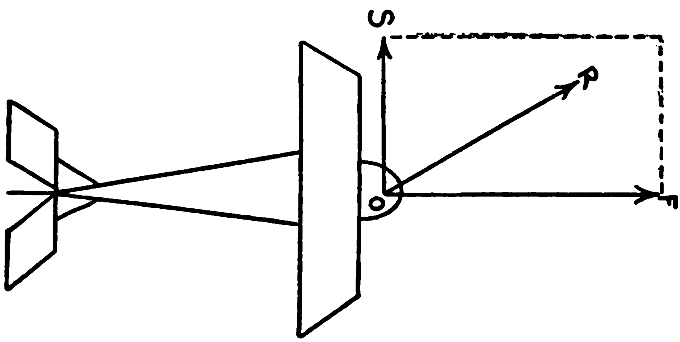

FIG. 68.—THE DRIFT OF AN AËROPLANE

its intended course as to miss completely its objective point.

Realizing these limitations to aërial navigation when steering by compass, the Sperry Gyroscope Company has developed a *drift indicator* which shows the exact direction of travel. This indicator, which is shown in Fig. 69, consists of a prismatic monocular telescope mounted in such a way that a clear vision of the ground below may be obtained.

When looking through the telescope, which is so made

that it is always in focus, five parallel hairs are seen across the field of vision. On account of the speed of the aëroplane all objects seen through the telescope pass

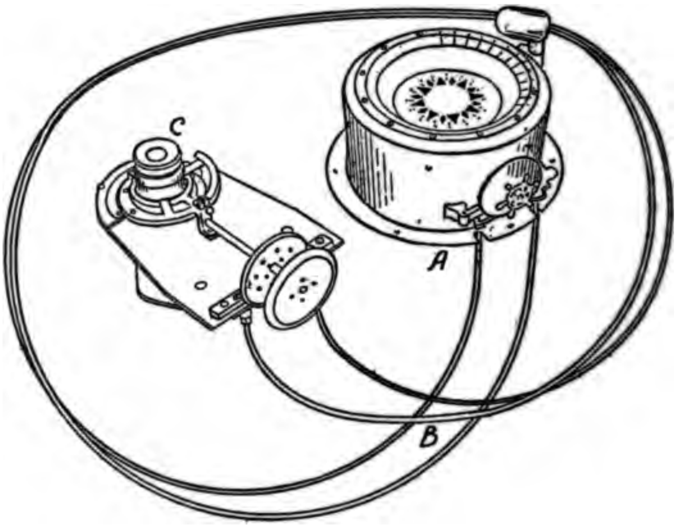

FIG. 69.—FINDING YOUR WAY THROUGH THE AIR

The Sperry Synchronized Drift Set for determining and compensating for the drift of an adjustable *lubber line*. Compass A, synchronously connected by double wires, B, so that when the drift of the aëroplane is determined by the telescope of the lubber line on the compass telescopic drift indicator, C, is automatically set.

so quickly that they look like a stream of closely-knit lines having almost perfect directional qualities.

In using the indicator it is simply necessary to turn the telescope C in its frame by the handle marked D, until the hairs just mentioned are parallel to the stream

lines passing the field of vision, and this is very easy to do. A pointer fixed to the telescope makes it possible to read on a graduated scale attached to the frame the angle between the true course taken by the aëroplane and the apparent course or longitudinal axis of the machine.

A steel wire passing through flexible tubes connects the telescopes with the adjustable *lubber line*[1] of the compass so that it is never necessary to read the pointer of the telescope except for checking. The lubber line of the compass automatically takes up its proper position exactly to correct for *drift*.

When in use the pilot simply holds his heading, following the original instruction only, the lubber line being constantly shifted by the observer exactly to compensate and correct for drift. In this way the aëroplane is always held to its proper course, and hence will reach the desired destination.

The compass used in this set is the well-known Sperry adjustable lubber line air compass. The compass bowl is supported from the outer shell by springs for protection against vibration of the aëroplane and the shock of landing. The compass card and the lubber line are painted with a luminous compound so that the card can be read in the dark at a distance of three feet. The weight of the drift indicator and compass complete is only 7½ pounds.

[1] A line drawn on the inside of a compass to indicate the ship's bow.

APPENDIX C

HOW TO MAKE AËROPLANE CALCULATIONS

If you are a scientist, a technical engineer, or an aëroplane builder you can, of course, figure out the *minimum horse power,* the *gliding angle,* the *climbing speed* and other *characteristics,* as they are called, of an aëroplane by making the calculations in the usual way—that is, if you have the time.

On the other hand, if you are not a *shark* at working out aëronautical *math* problems, or if you are just the average man who knows nothing about such calculations but want the results, then you should get a *Triple-Slide-Rule Aëroplane Calculator,* which will enable you to calculate any of the following characteristics of any aëroplane in an easy way and one which you can learn in a little while.

The Characteristics of an Aëroplane.—With this calculator you can find

The speed	The minimum horse power
The landing speed	The reserve horse power
The maximum speed	The altitude record
The minimum speed	The gliding angle
The climbing speed	The weight

The altitude speed	The area of surface
The economical speed	The wing curve
The range of speed	The useful load
The range of distance	The highest possible weight

Fuel capacity for time and distance flying
Speed and horse power for different angles of incidence
The horse power required for different altitudes
The maximum horse power required for different characteristics
The total head resistance in pounds, created by any certain speed

How the Calculator Works.—The reason this aëroplane calculator is called the *Triple-Slide* is because it has three slides numbered 1, 2, and 3, and there is also one turnable indicator, as shown in Fig. 70.

Slide No. 1 is known as the *wing curve slide;* it shows a wing curve of some particular type of machine, as for instance a Farman wing, with three scales, a *monoplane* (M), a *staggered biplane* (St. B) and a *vertical biplane* (V B) scale.

Each scale has two curves, one of which is shown in full line and the other in dotted line, and they are both marked at certain intervals to show the angle of *incidence* and the *lift.* The full line is to be used in making all other calculations. On the right-hand side of each scale is the *lift coefficient* indicated by the letter L.

Slide No. 2 is known as the *power slide,* and this

slide is used in every calculation in which the *horse power* is a factor.

Slide No. 3 is known as the *speed slide,* and it is used in every calculation in which *speed* is a factor.

The turnable indicator has one curved line and one straight line. The straight line is used in connection

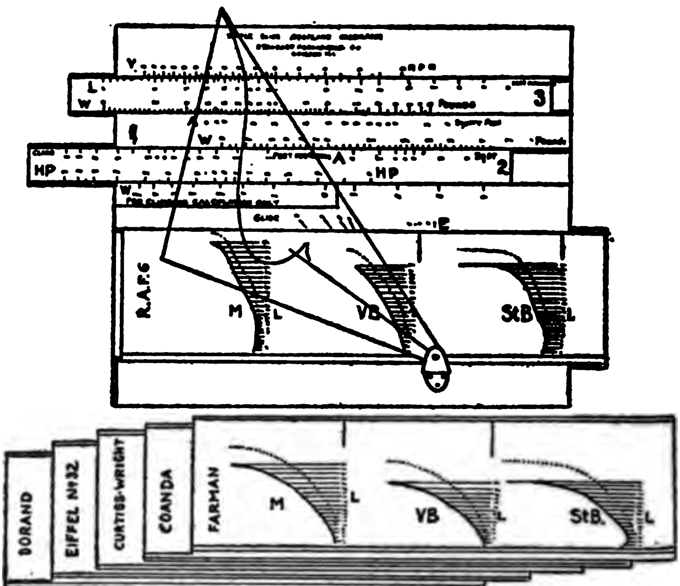

FIG. 70.—A TRIPLE SLIDE AËROPLANE CALCULATOR MAKES AËROPLANE CALCULATION EASY

with the full line on Slide No. 1, and also in calculating the gliding angle from the dotted line. The curved line is used to intersect the *horse power* on Slide No. 2.

The *base* of the instrument is numbered 4, 5, and 6.

Aëroplane Terms and Symbols with Definitions. The main factors of an aëroplane are:

(A) The supporting planes or area of surface (figured in square feet)

(W) The weight (figured in pounds)

(DH) The deadhead resistance (figured in square feet)

(HP) The power plant (figured in horse power)

Deadhead Resistance (*DH*).—This is the structural head resistance of all parts taken together, but not including the supporting surfaces, and measured as a vertical plane in square feet. The absolute amount of deadhead resistance is but seldom known, as it requires the building of an exact scale model of the aëroplane, which then has to undergo a laboratory test. The approximate deadhead resistance is used and is derived from knowing the laboratory test of standard constructions, such as wires, struts, etc. In giving the following deadhead resistances of the different types of aëroplanes, we take into consideration only the best types of streamline forms and standard constructions. The DH should be cut down in every possible way.

Efficiency of Construction (*E of C*).—This is equivalent to the number of times the area of surface is greater than the deadhead resistance of A/DH. For example: If the area of surface is 400 sq. ft. and the deadhead

	Sq. Ft. of Surface	Sq. Ft. DH.
Speedy monoplane using	100 to 150	6
Monoplane using	200 to 300	7 to 9
Speedy Scout biplane using	150 to 200	7 to 8
Tractor Exhibition biplane using	350 to 450	9 to 10
Pusher Exhibition biplane using	300 to 450	11 to 12
Heavy fighting biplane using	450 to 500	13 to 14
Battleplane using	500 to 600	13 to 15
Two motored battle plane using	600 to 700	16 to 20
Hydroplane using	350 to 400	10 to 12
Flying boat using	350 to 450	12 to 14

resistance is 10 sq. ft., the E or efficiency of construction is then 400/10 or 40.

Gliding Angle (*GA*).—Whenever the motor stops or is stopped, the aëroplane is forced to come down. The pilot prevents it from falling, by means of the control surfaces making it glide through the air. The ratio of the distance it will glide before touching the ground to the altitude or height it was in when starting to glide, is known as the *gliding angle*. For example: The aëroplane is 1,000 feet high and can glide over a distance of 8,000 feet before touching the ground, which makes the gliding angle 1 to 8, the gliding power being eight times the distance of the height. The gliding angle of an aëroplane is regulated by the deadhead resistance and the area of the surface.

Example of Calculation.—Now suppose you want to calculate the *horse power* for a certain *angle of incidence* when the aëroplane is in horizontal flight. Find

the *weight* (W), the area of surface (A), and the *dead-head resistance* (DH).

Calculate E (see definition above). On slide 1 connect the arrow with the found E. On slide 2 connect the W with A. Turn the indicator to the proposed angle of incidence (on the full line). Looking on slide 2 you will find the indicator crosses it at a certain point, which is the *horse power* for the above proposed *angle of incidence* in horizontal flight.

Example in Figures

W equals 2,000 pounds, flying weight.

A equals 400 square feet.

R. A. F. = 6-wing curve, VB = 6-degree angle incidence.

Tractor Exhibition Biplane equals 10 square feet DH.

E = A/D = 400/10 = 40. On slide 1 connect the arrow with E40. On slide 2 connect W2000 with A400. Turn the indicator to the 6-degree angle of incidence on the full line. We find the indicator intersects slide 2 at 3, which is the horse power required for *horizontal flight* at the stipulated *angle of incidence.*

APPENDIX D

AEROPLANE CALCULATIONS

About Aëroplane Calculations.—All aëroplane calculations are based on the used wing curve. There is no process or system known by which aëroplane calculations can be made without knowing the *laboratory test* of the *wing curve.*

The characteristics of the *wing curve* which influence the results of any and all aëroplane calculations are known as the *lift and drag coefficients.* The ratio of the *drag* to the *lift* is known as the *effectiveness of the wing.*

Every wing or plane moved against the air or held stationary in a current of air creates a certain amount of backward "pull," which is known as the *drag.* The *drag* is always contrary to the forward motion of the aëroplane and is measured by the laboratory test, giving the amount of "pull" created by a wing of one square foot when moved horizontally one mile per hour under a certain *angle of incidence.* This measurement is known as the *drag coefficient,* as it is multiplied by the number of square feet used in the wing, and the square of the speed in miles per hour attainable by the aëroplane, to give the entire drag of the wing.

The *lift* is the power of the wing to overcome gravity, and is always vertical to the forward motion of the

aëroplane. The *lift* is measured by the *laboratory test,* giving the number of pounds a wing of one square foot can lift when moved horizontally one mile per hour under a certain angle of incidence. This measurement is known as the *lift coefficient,* as it is multiplied by the number of square feet used in the wing and the square of the speed in miles per hour attainable by the aëroplane to give the entire *lift* of the wing.

There is no one wing curve that will give the best results for every important characteristic of an aëroplane—for example: the speediest aëroplane obtainable cannot use the same wing curve that is required to carry the greatest amount of weight, etc.

It is impossible to build an aëroplane that will give you the highest *aërodynamical efficiency* unless you build it according to the *lift and drag coefficient* of the *wing curve* you use. In attempting to build an aëroplane without knowing these coefficients it is simply a hit-or-miss proposition. It will fly, no doubt, but this is all you can say for it.

Five standard *wing curves* on slides complete to calculate monoplane, staggered biplane and the vertical biplane are supplied with the *triple-slide aëroplane calculator,* and extra slides of any laboratory tested wing curve can be had at a nominal cost; altogether there are about twenty of them in use at home and abroad.

Although every factor and characteristic is based on the used *wing curve,* it is equally true that, vice versa,

every *wing curve* is based on the factors and characteristics. It is therefore readily seen that you can calculate backwards and forwards from the factors and the characteristics to get the best suited *wing curve* for them.

With the *wing curve* furnished with the calculator you can calculate every characteristic and the main factors of any aëroplane or any proposed design of aëroplane—for example: Let us take a *military tractor* with 410 square feet of surface and a construction weight of 1,690 pounds, using a certain *wing curve* with a 135-horse-power motor. With a few movements of the slide you will find that it can carry a useful load of 1,260 pounds. You also find that by using a useful load of 960 pounds and a 6-degree angle of incidence you have a minimum horse power of $54\frac{7}{10}$ at a speed of 65 miles per hour. By changing the angle of incidence to $1\frac{1}{2}$ degrees you will find it has a maximum speed of 103 miles per hour and a minimum speed of $49\frac{6}{10}$ miles per hour, climbing speed of 846 feet per minute, landing speed of $49\frac{6}{10}$ miles per hour, the gliding angle to be 1 to 9, the highest altitude obtainable 24,160 feet, at which you have a speed of 85 miles per hour, and you keep on calculating until you have all the characteristics and the main factors of this aëroplane right before you and all in a very short length of time.

If you are designing an aëroplane a little time with the *triple-slide* shows you exactly what you want to know—if you have to cut down the head re-

sistance, if you have to cut down the weight, or if it is possible to have more head resistance or carry more weight and still accomplish the desired results. If you want a speedy aëroplane, a heavy duty weight-carrying aëroplane with a certain stipulated speed, an altitude-record-breaking machine, a medium exhibition aëroplane, in fact no matter what type or kind of aëroplane you want, the *triple-slide* will show you what *area of surface,* what *horse power,* what *weight,* what *wing curve,* in fact, it will tell you just what you have to consider, and give you the answer at the same time.

APPENDIX E

AVIATOR OUTFITS

A pilot should be dressed properly to fly; not that he will fly the better, but that he may be more comfortable and that his landings may be made safer.

Aviators' suits are made to order by the A. G. Spalding Company and Abercrombie and Fitch, both of New York, and may be had in either khaki-colored or olive-drab army cloth. The breeches are like those used for riding, as shown at A in Fig. 71.

Helmets with special padded tops and sides built on a heavy leather form with ear cones and felt lining, adjustable visor fronts, and extra protection at the back, as shown at B, are now worn by aviators. A leather hood, C, with wool fleece lining is worn underneath the helmet.

An *ilanasilk* life preserver like that shown at D is worn by many aviators, so that if they should fall into the water their heads will be held above it. The safety device shown at E is used to strap the aviator to his seat. It consists of webbing straps, rings, buckles, and a releasing scheme that is bound to work when it is operated.

Keeping Up with the Art.—Finally let me urge that you read regularly some good paper on flying; I prefer *Aviation and Aëronautical Engineering*, whose publication offices are at 120 West 32d Street, New York City.

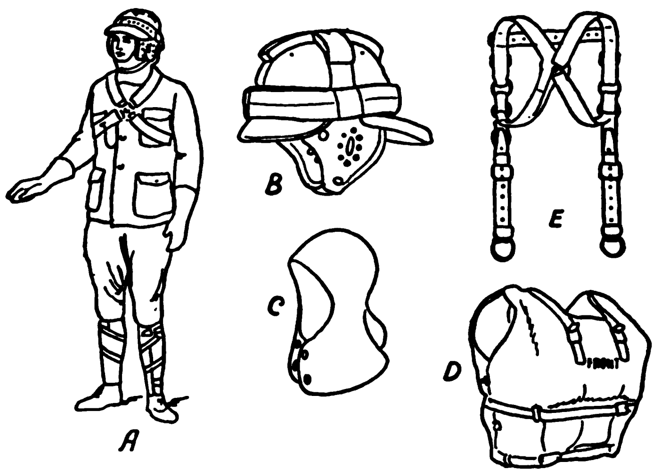

FIG. 71.—AN AVIATOR'S OUTFIT. A.—AVIATOR IN UNIFORM. B.—HELMET. C.—LEATHER HOOD. D.—SAFETY DEVICE. E.—LIFE PRESERVER.

The changes and advances in aviation are taking place with marvelous rapidity and the way to keep up with all that is going on in the world of flight is to read what a corps of trained men have to say about it in the paper I have mentioned above.

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SQUADRON ORGANIZATION

	Head-quarters Section	Supply Section	Engineer Section	12 Aëro Sections	Attached Medical Corps	Total
Major.........	1					1
Captains and Lieutenants	1	2	2	12	1	18
Enlisted Men..	10	37	19	84	4	154
Motor Cars....	1					1
Motor Trucks..	1	8	4	12		25
Motorcycles...	2	2	2			6
Airplanes......				12		12

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